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The Dentition of Eastern Pacific Mulletts, with Special Reference to Adaptation and Taxonomy<sup>1</sup>

ALFRED W. EBELING

ALTHOUGH tooth characters are valuable in the taxonomy of mulletts, descriptions of their dentition have generally been superficial and not quantitative. Furthermore, in these descriptions (with the notable exception of those of Schultz, 1946 and Thomson, 1954a-b), there has been little evaluation of tooth characters in respect to their value in classification, particularly as between species of *Mugil*. Uncertainties regarding the value of tooth characters in the distinction of species of eastern Pacific mulletts were first brought to my attention by Dr. Boyd W. Walker at the University of California, Los Angeles.

The unusual feeding habits of mulletts indicate a high degree of interspecific trophic specialization and, consequently, well-defined differences in their dentition. Schultz (1946) recognized, "...that the mouth parts of mugilid fishes have evolved and specialized, whereas the other anatomical structures have remained more or less constant for most of the genera." Schultz, Thomson (1954a-b), and Smith (1935), among others, have found unifid, bifid, and trifid teeth in the various genera of mulletts. In addition to those on the jaws, some genera have teeth on the tongue (*Chaenomugil*), on the vomer and palatines (*Agonostomus*), or on the palate and tongue (*Joturus*, *Valamugil*). The oral teeth are restricted to the jaws in *Mugil* and *Xenomugil* (Schultz, 1946). Most mulletts have toothed pads on the posterior roof of the pharynx.

This study is confined to the marine mulletts (Mugilinae) of the eastern Pacific, currently referred to three genera (Schultz, 1946). Two of the genera, *Xenomugil* and *Chaenomugil*, are represented by the single well-defined species *X. thoburni* and *C. proboscideus*. The eastern Pacific species retained in *Mugil* are referable to the sharply distinct *curema* and *cephalus* species groups, generally distinguished by scale and fin-ray characters. In addition, I

find that the inner teeth in the *curema* complex are simple; those in the *cephalus* assemblage bifid. Within each species group of *Mugil* there are recognized three species which stand in need of more thorough comparison and appraisal. The *curema* group includes *curema*, *setosus*, and *hospes*; the *cephalus* group, *cephalus*, "*peruanus*", and *rammelsbergi* (*M. "rammelsbergi"* from the Galápagos Islands may be a more extreme form than the mainland species, which was unavailable for study).

## METHODS AND MATERIALS

An investigation was made of the morphology and histology of mullet teeth by means of dissections and microtome sections. The data obtained formed the basis for certain conclusions on the methods of tooth development and replacement in the aforementioned species. Since mullet teeth are generally minute, microscopic methods must be used to accurately determine their sizes, shapes, and arrangements.

In the observation of each specimen, dissecting needles were used to lift the gum away from the teeth so that their shape and arrangement could be observed. A thin jet of air would dry and shrivel the gum surrounding the teeth, rendering them more easily discernible. Using these methods, the gross arrangements and patterns of the teeth were revealed.

Young and half-grown specimens of *Mugil curema* were cleared in potassium hydroxide and stained in alizarin. Upper jaws of all the species except *M. setosus* were excised, skinned, cleared, and stained. Cross sections of these were obtained by carefully slicing through the jaw with a fine scalpel. Tooth attachments and replacement mechanisms were especially noted.

Individual teeth from both the upper and lower jaws were removed from all specimens studied. Balsam mounts of whole teeth, as well as small sections of gum with the embedded

<sup>1</sup>Contributions from the Scripps Institution of Oceanography, New Series, No. 937.

smaller teeth, were prepared. In these mounts there were representatives of the primary and secondary teeth of the upper jaw, as well as teeth from the mandible and pharyngeal pads.

Upper-jaw and mandibular teeth from 46

specimens of *Mugil curema*, 24 of *Xenomugil thoburni*, 22 of *Mugil hospes*, 5 of *M. setosus* (Stanford University paratypes No. 309), 22 of *M. cephalus*, 12 of *M. rammelsbergi* (these were collected in the Galápagos Islands and

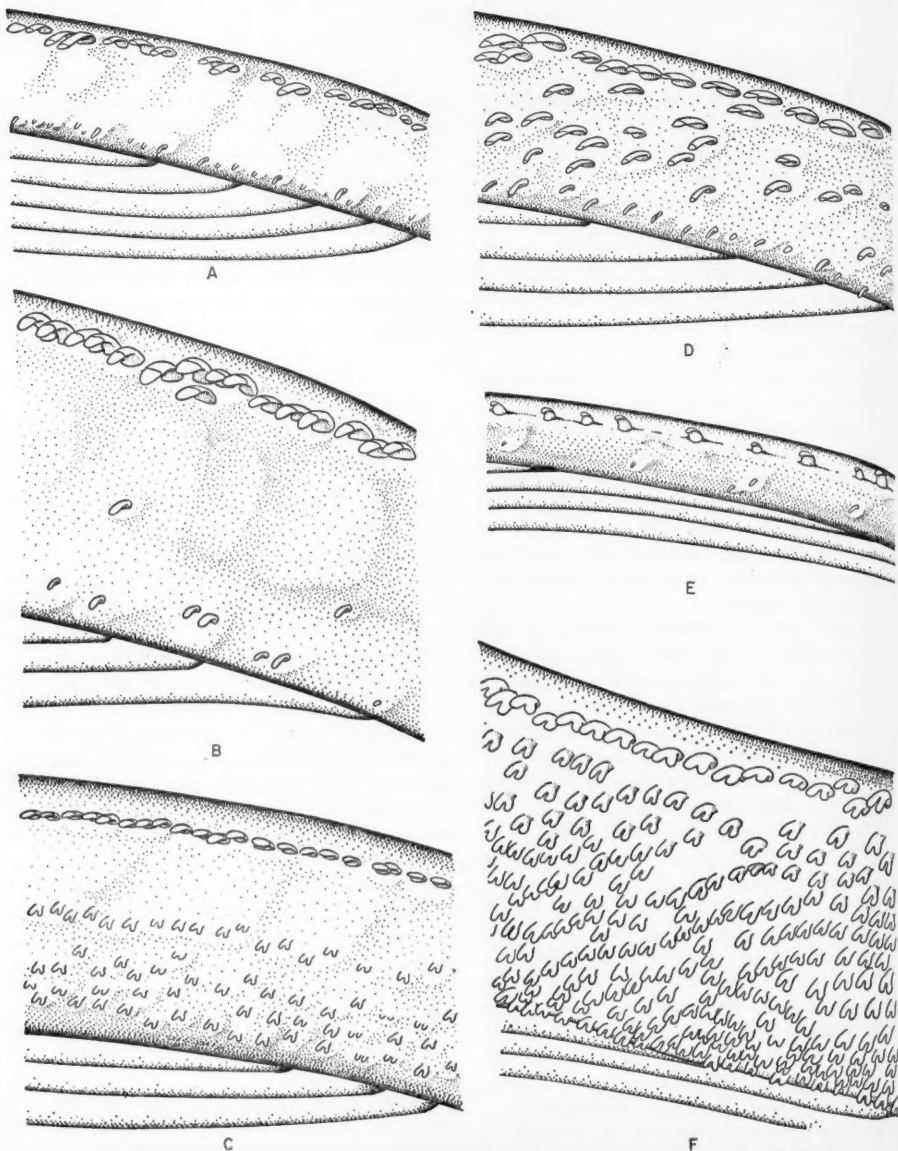


Fig. 1. Inner surfaces of the upper jaws showing typical parts of the mid-sections containing primary and secondary teeth. A, *Mugil curema*; B, *Xenomugil thoburni*; C, *Mugil cephalus*; D, *M. setosus*; E, *M. hospes*; F, *M. rammelsbergi*.  $\times 17$ .



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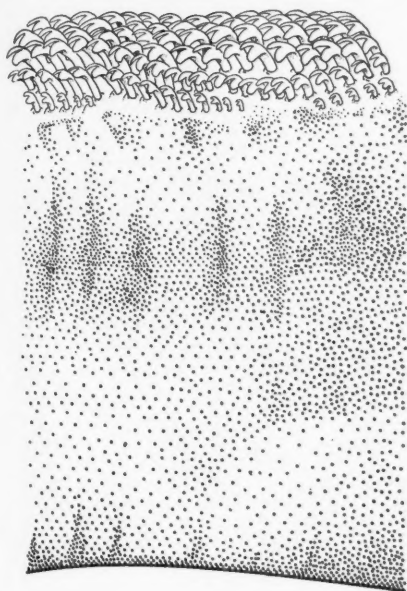


FIG. 2. Inner surface of the upper jaw of *Chaenomugil proboscideus*, showing a typical part of the mid-section containing primary teeth.  $\times 17$ .

have not been compared with the mainland species), and 12 of *Chaenomugil proboscideus* were temporarily mounted on slides and their lengths measured with an ocular micrometer to the nearest hundredth of a millimeter. The length was considered to be the oblique distance from the enamel tip of the tooth to the farthest angle of the base. The teeth of *Chaenomugil proboscideus* are difficult to measure because the embedded ends of their long bony bases are often damaged during extraction. A faint partition was found near the base of the overt tooth, however, and the tooth length was taken as the oblique distance from an enamel tip to the anterior edge of this partition. Teeth measured from each specimen were taken from the group in the primary row nearest the symphysis of the upper jaw. The largest teeth in the jaw are usually in this group. The largest and most perfect tooth was extracted for measurement. Along with the measurements, information was obtained on the tooth arrangements, degree of completion of the rows of teeth, condition of the teeth and gums, and other pertinent features. Counts were made of the teeth in both the primary and the second-

ary row of the right half of the upper jaw and the mandible. The tooth lengths were plotted against the standard lengths of the fish from which they were extracted.

Cross and frontal sections were made from the jaws of 12 specimens representing 3 species (*Mugil curema*, *M. cephalus*, and *M. hospes*). The jaws were decalcified, embedded in celloidin, and sectioned. The sections were stained in acid Harris hematoxylin solution and counterstained in eosine. Photomicrographs and drawings were made of the clearer mounts.

#### TOOTH MORPHOLOGY

Mullet teeth range in size, shape, and structure from the minute, almost microscopic, teeth of *Mugil hospes* to the relatively complex, bifid, scoop-like teeth of *Chaenomugil proboscideus*. They also differ interspecifically in arrangement and attachment. Both the primary and secondary teeth are arranged uniserially or in bands and the primary teeth are attached to the jaw bone by either short or long fibers. Certain general conclusions on the arrangement, attachment, size, shape, and structure of mullet teeth are presented as a background for the observations on growth, development, and interspecific differences to follow.

**ARRANGEMENT.**—The primary or external row comprises relatively large teeth occupying the more prominent position in the jaw. The primary teeth in the upper jaw of the genera *Mugil* and *Xenomugil* that were studied are below the premaxillary bone (Figs. 1 and 3). In these genera this row is uniserial. In some specimens the teeth are in groups of 2 to 3, with the center tooth of the triad usually the longest. This center tooth may be the oldest in the group. The upper-jaw teeth of *Chaenomugil proboscideus* are in a compact band, in sharp contrast to the usual uniserial condition (Fig. 2).

The secondary row or band is composed of smaller teeth just behind the primary row, from which they are separated by a toothless area of gum. Minute teeth are developed here in all species except *Chaenomugil proboscideus*. Depending upon the species, these teeth are either widely scattered, aligned in a single row, or arranged in a band (Figs. 1 and 3).

The mandible contains, in general, only primary teeth; however, the members of the

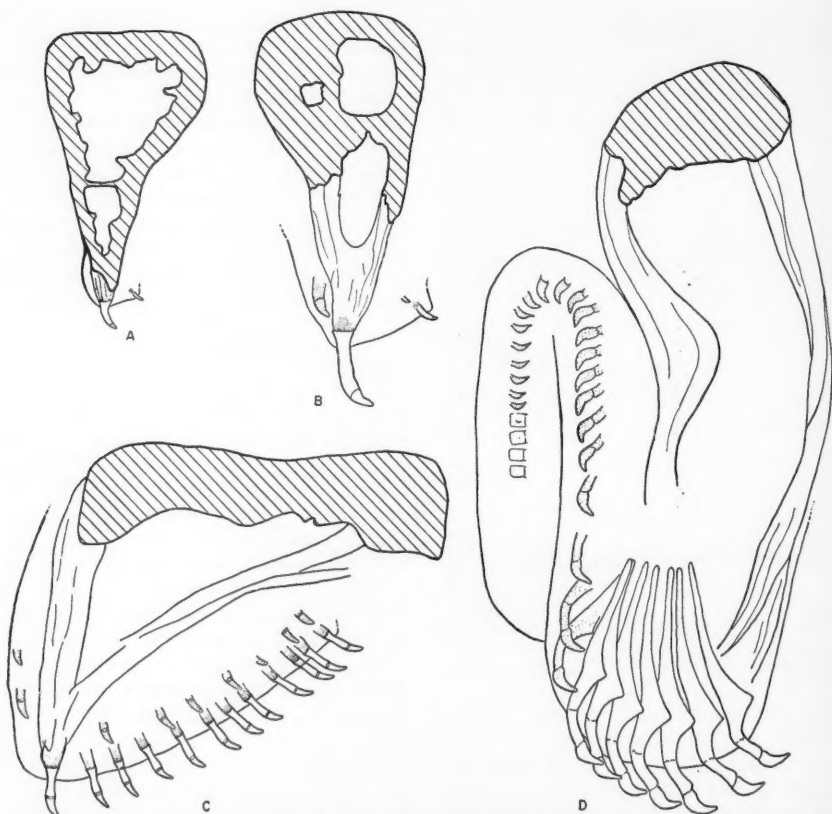


Fig. 3. Typical cross-sections from the mid-sections of the upper jaws of A, *Mugil hospes*; B, *M. curema*; C, *M. rammelsbergi*; D, *Chaenomugil proboscideus*. The functional teeth and fibrous attachment strands are outlined, the replacement teeth and partially ossified bases of the primary teeth are stippled and the premaxillary bone is hatched. Parts of the epidermis and dermis are omitted.  $\times 35$ .

*Mugil cephalus* group have both primary and secondary teeth. The mandibular teeth are uniserial in all species except *C. proboscideus*, in which they are in bands similar to those of the upper jaw, and in *Mugil cephalus* and *M. rammelsbergi*, which have a band of secondary teeth.

**ATTACHMENT.**—The primary teeth of the upper jaw are not ankylosed to the premaxillaries, but are attached by fibrous strands (Because of their flexible attachment with the jaw bones, mullet teeth appear loosely mounted and are easily movable in the gum). These strands are aligned in two rows, one at the external margin and one at the internal margin of the jaw bone, in all species except *Mugil*

*hospes*, which has teeth set rather near the premaxillary (Fig. 3 A and Pl. I C). The thicker external strands descend perpendicularly from the long axis of the jaw bone, but, in general, the internal fibers are more narrow in diameter and descend obliquely. A pair of such strands coalesces ventrally to form a fibrous base for each functional tooth (Fig. 3 B-C and Pl. I D). Figure 4 represents a section through two adjacent strands in both the internal and external rows. The proximal part of one strand (att. fib. pmx.) and the distal part of its neighbor (att. fib. pr.) are shown. The internal and external strands remain separate in *Chaenomugil proboscideus* and only the internal fibers appear to have any connection

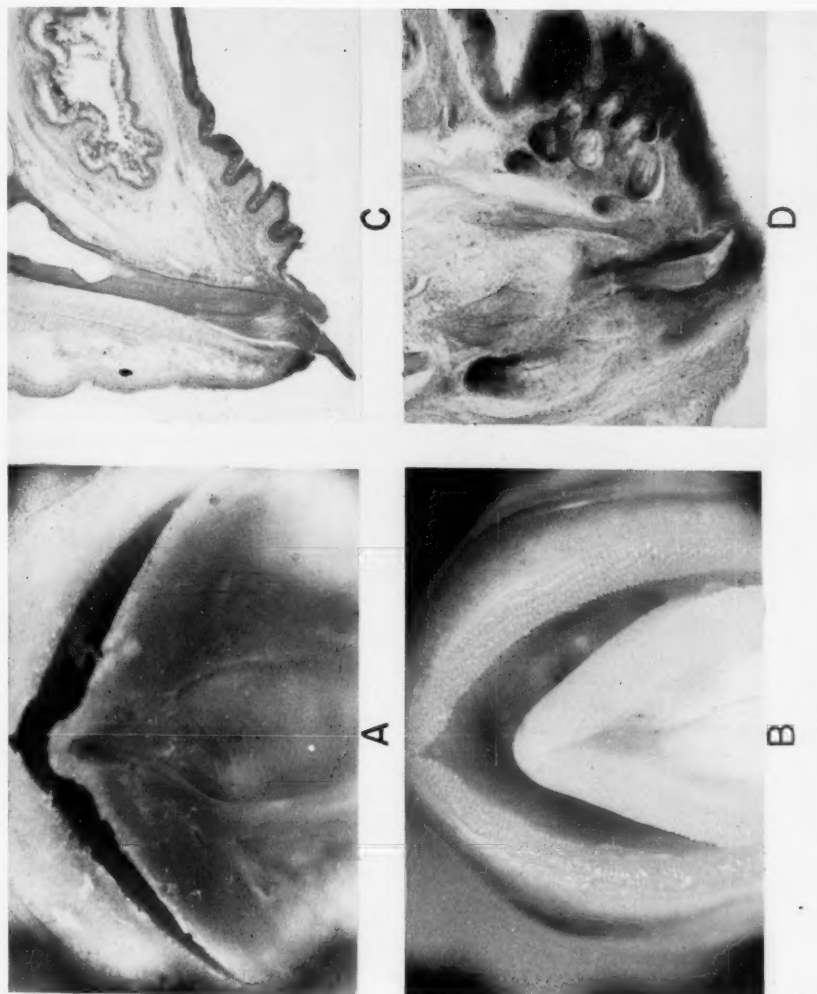


Plate I. Lips and teeth of A, *Mugil rammeisbergi*, and B, *Chaenomugil proboscideus*, X6.7. Cross-sections from near the symphysis of the upper jaw of C, *Mugil hospes*, and D, *Mugil cephalus*; X66.



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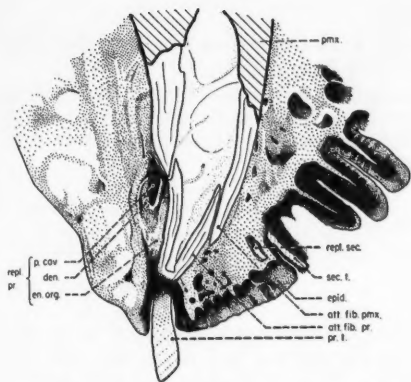


Fig. 4. Cross-section from near the symphysis of the upper jaw of *Mugil curema*. att. fib. pmx., proximal part of attachment fibers; att. fib. pr., distal part of attachment fibers; den., dentine; en. org., enamel organ; epid., epidermis; p. cav., pulp cavity; pmx., premaxillary bone; pr. t., primary tooth; repl. pr., replacement bud for primary tooth; repl. sec., replacement bud for secondary tooth; sec. t., secondary tooth.  $\times 52$ .

with the functional teeth (Fig. 3 D). The functional teeth generally rest on short, partially ossified bases (Fig. 3 A-C). The teeth of *C. proboscideus*, however, have long thin bony bases which are deeply embedded in the gum area between the internal and external fibrous strands (Fig. 3 D).

The species that have wide lips (*C. proboscideus* and *Xenomugil thoburni*) also have very long attachment fibers in the jaws. The thin-lipped species (*Mugil hospes* and *M. curema*) have relatively short fibers. In *M. hospes* these fibrous strands are shorter than the teeth and do not bifurcate. *M. rammelsbergi* has a wider, flatter jaw bone than the other species; consequently, the internal fibrous strands extend diagonally from the posterior margin of the premaxillary bone to the functional tooth at the anterior margin of the jaw (Fig. 3).

The smaller secondary teeth in the upper jaw are loose in the gum. They are apparently not connected by fibers to the premaxillary bone (Figs. 3, 4 sec. t., Pl. I D).

In all the species the mandibular teeth are associated with the dentary bone in the same manner as the upper-jaw teeth are associated with the premaxillary. Usually, however, the annectant fibrous strands of the mandible are relatively longer than those of the upper jaw.

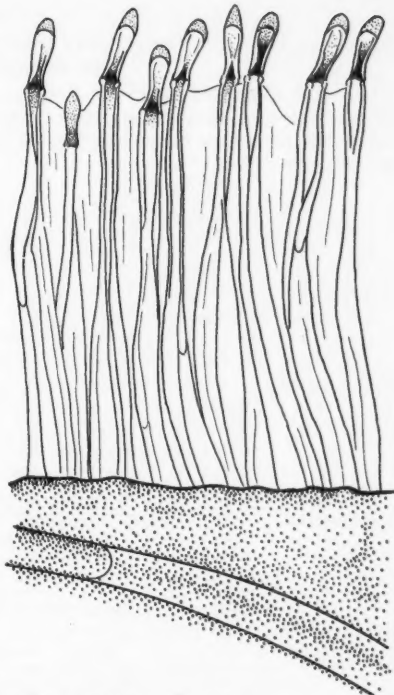


Fig. 5. Typical part of the lower jaw of *Mugil curema*, with the gum removed.  $\times 29$ .

In *Mugil curema* they are several times as long (Fig. 5).

**SIZE AND SHAPE.**—The teeth of the eastern Pacific Mugilinae vary in size among individuals of the same species or even within a particular series in a single jaw. For example, the primary teeth in both the upper and lower jaws are largest near the symphysis and decrease in size near the extreme distal ends. Also the newly erupted replacement teeth are always smaller than the functional teeth. The primary upper-jaw teeth are larger and stronger than either the primary mandibular teeth or the secondary teeth. The primary mandibular teeth are sometimes only slightly smaller than those of the upper jaw; however, they are less than one-half the size of the upper jaw teeth in *Mugil setosus* and some specimens of *M. curema*. The secondary teeth are generally minute; in *M. hospes* the secondary teeth sometimes require a compound microscope for detection, whereas the secondary bifid teeth of

TABLE I

TOOTH COUNTS AND SIZE RANGES IN THE RIGHT HALVES OF THE PRIMARY AND SECONDARY UPPER JAW AND MANDIBULAR TOOTH ROWS

The ranges of the tooth lengths are given as ten-thousandths of the standard length; the number of specimens is in parentheses. All counts and measurements are of the teeth in the right halves of the jaws, and, in each instance, the tooth measured is the largest and most perfect tooth near the symphysis of the jaw (see under methods).

Species	Standard length (mm.)	Teeth in primary upper jaw row		Teeth in secondary upper jaw row		Teeth in mandibular row	
		No.	Length	No.	Length	No.	Length
<i>Mugil curema</i>	29-57 (6)	21-30 (6)	59-68 (6)	0-1 (6)	—	21-42 (5)	23-35 (5)
	68-103 (7)	24-36 (6)	44-72 (7)	7-40 (4)	—	28-51 (4)	24-34 (3)
	108-172 (15)	28-48 (15)	32-53 (15)	11-60 (8)	13 (1)	41-73 (15)	19-29 (8)
	186-292 (18)*	40-63 (18)	18-30 (16)	4-68 (14)	6-8 (4)	74-115 (16)	9-18 (12)
<i>Mugil setosus</i>	118 (1)	—	61 (1)	—	—	—	—
	174-200 (4)	—	35-43 (4)	—	12-28 (4)	—	20 (1)
<i>Mugil hospes</i>	29-38 (5)	8-23 (5)	24-27 (5)	0 (5)	—	0 (5)	—
	97-119 (4)	26-37 (4)	13-16 (4)	0 (4)	—	65-84 (4)	9-10 (2)
	125-155 (8)	30-73 (8)	11-16 (8)	0 (8)	—	70-120 (8)	8-10 (8)
	162-186 (5)	30-75 (5)	8-10 (5)	2-30 (5)	4 (1)	115-130 (4)	8 (1)
<i>Mugil cephalus</i>	25-34 (6)	20-29 (6)	41-52 (6)	0-15 (6)	—	6-15 (6)	37-47 (5)
	49 (1)	58 (1)	36 (1)	—	—	45 (1)	—
	115 (4)	70 (1)	29 (1)	Many (1)	—	91 (1)	22 (1)
	148-183 (6)	70-95 (6)	19-21 (6)	Many (6)	9 (1)	100-104 (6)†	13-17 (6)
<i>Mugil rammels- bergi</i>	190-250 (8)	57-101 (8)	14-18 (8)	Many (8)	8-9 (2)	97-149 (8)‡	10-14 (8)
	29-34 (5)	23-26 (5)	43-46 (5)	30-45 (5)	—	9-17 (5)§	27-31 (5)
	46 (1)	32 (1)	38 (1)	73 (1)	—	20 (1)¶	28 (1)
	131-140 (3)	55-75 (3)	17-21 (3)	Many (3)	—	51-63 (3)	13 (3)
<i>Xenomugil thoburni</i>	146-185 (3)	54-80 (3)	16-18 (3)	Many (3)	10-12 (2)	60-75 (3)	10-13 (3)
	37 (1)	25 (1)	70 (1)	0 (1)	—	5 (1)	—
	53-61 (2)	63-80 (2)	79-80 (2)	0 (2)	—	60-70 (2)	64-72 (2)
	69-94 (4)	63-82 (4)	66-74 (4)	0 (4)	—	62-87 (4)	51-58 (4)
<i>Chaenomugil proboscideus</i>	99-135 (10)	56-95 (10)	50-60 (10)	0-4 (10)	—	57-95 (10)	39-50 (10)
	148-169 (5)	73-91 (5)	40-52 (5)	8-25 (5)	17 (1)	70-89 (5)	36-47 (5)
	182-268 (2)	100 (2)	34-35 (2)	44-60 (2)	15 (1)	90-100 (2)	29-33 (2)
	41-45 (4)	3-4 rows (4)	38-44 (3)	—	—	2-3 rows (4)	31 (1)
<i>Chaenomugil proboscideus</i>	49-79 (5)	5 rows (5)	45-51 (5)	—	—	5-6 rows (5)	32-37 (2)
	92-122 (3)	5-6 rows (3)	43-49 (3)	—	—	7 rows (3)	30-31 (3)

\* Small-toothed specimens from Cape San Lucas and Socorro Island.

† In the size range from 148 to 183 mm, the teeth in the secondary mandibular band increase from 0 to more than 100.

‡ In the size range from 190-250 mm, the teeth in the secondary mandibular band are numerous.

§ In the size range from 29 to 46 mm, the teeth in the secondary mandibular band increase from 1 to 8.

|| In the size range from 131 to 185 mm, the teeth in the secondary mandibular band are numerous.

the *M. cephalus* group are easily discernible at low magnification under a dissecting scope (Table I and Fig. 6).

The simplest type of tooth (e.g., that of *M. curema*) is shaped like the end of an upholsterer's needle, that is, slightly flattened and curved inward at the tip (Fig. 6E). The more specialized teeth of other species are bifid. Those of *Chaenomugil proboscideus* are shaped like miniature claw crowbars with the bifid tips and adjacent margins forming minute

scoops, and are attached to long flexible bony bases (Fig. 6G). The mandibular teeth are similar in form to the primary upper jaw teeth, while the secondary teeth (those of *M. cephalus* excepted) are generally minute counterparts of the primary teeth.

STRUCTURE.—The general plan of mullet tooth construction follows that of most teleosts. The bony dentine areas and pulp cavity, appearing black in some microscope preparations, can be easily seen (Figs. 4 den., p. cav., and



Fig. 6. E, *M. c.* of a primary upper-jaw tooth from left side and the G side.

6 E). Korff's contribution to enamel calcification.

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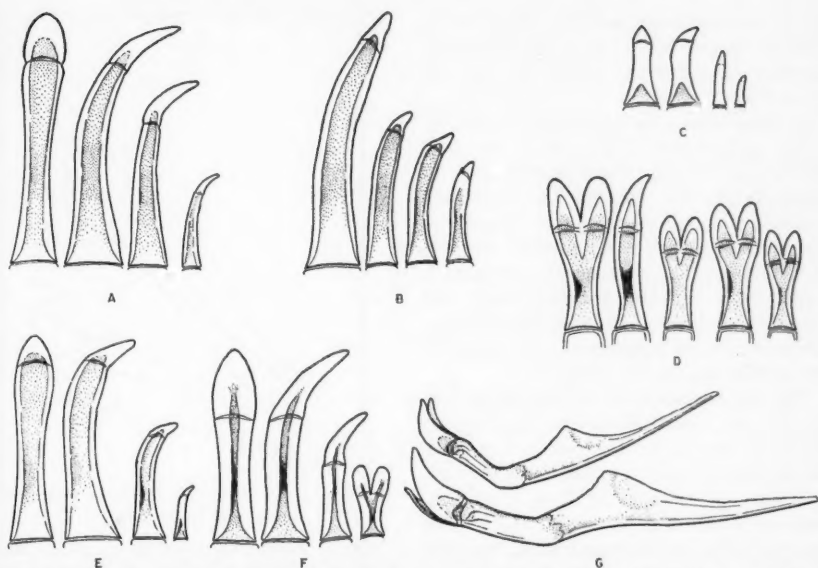


Fig. 6. Typical teeth of A, *Xenomugil thoburni*; B, *Mugil setulosus*; C, *M. hospes*; D, *M. rammelsbergi*; E, *M. curema*; F, *M. cephalus*; G, *Chaenomugil proboscideus*. In A, C, E, and F both frontal and side aspects of a primary upper-jaw tooth are shown, followed, from left to right, by a mandibular and a secondary upper-jaw tooth. In B the side aspects of one primary and 3 secondary upper-jaw teeth are shown. In D, from left to right, the front and side aspects of a primary upper-jaw tooth, a primary mandibular tooth and the front aspects of a secondary upper-jaw tooth, and a secondary mandibular tooth are shown. In G side aspects of a mandibular tooth (upper) and upper-jaw tooth (lower) are shown.  $\times 61$ .

6 E). The pulp cavity contains the "fibers of Korff", which, according to Levi (1939 a-c), contribute to the formation of dentine and enamel, i.e., these fibers may be the centers of calcium deposition.

Most teeth in both jaws have yellow tips at their apices. These tips are composed of what appears to be enamel, although the structure was not histologically determined. A distinct suture is visible between the tip and base of the tooth (Fig. 6). This is the weakest area of the tooth and is the first line of separation upon breakage. The tips are easily broken off by the slightest jarring from either dissecting needle or forceps. This may account for the absence of these tips on the teeth in some of the preserved specimens. The pulp cavity extends into the tip. The teeth of *Mugil hospes* apparently lack yellow tips; however, a suture is visible near the apex of the tooth (Fig. 6 C).

#### DEVELOPMENT

The growth and replacement of the teeth were investigated for whatever information

might be revealed that could be related to their ultimate structural characteristics. The descriptions of tooth replacement apply only to the adult mullets. The development of teeth in small juveniles was generally not investigated, although observations were made of the teeth in a few small pelagic specimens. Contrary to the condition as observed in many fishes, the replacement of the primary teeth of mullets proceeds from the front of the jaw posteriorly so that the rows of replacement teeth are external to the functional teeth. These are continually being supplanted so that smaller teeth give way to larger ones as the fish matures.

**REPLACEMENT.**—Since the primary teeth are loosely attached in the gum, they are presumably often lost and then replaced. This may account for the size differences of the teeth and for frequent gaps in the rows. The replacement teeth are generally anterior to the external row of fibrous strands in the jaws; in *Mugil hospes*, however, the developing teeth appear to be almost in the same vertical plane as the functional teeth. Apparently a replacement tooth

grows posteroventrad until it fills the space recently vacated by its functional predecessor. Another replacement tooth will then take its place (Figs. 3 and 4).

In *Mugil curema* the developing enamel (Fig. 4 en. org.), dentine (Fig. 4 den.), and pulp cavity (Fig. 4 p. cav.) of the replacement tooth are easily seen. The posteroventrad growth and movement of the tooth brings it alongside of the functional tooth of the primary row that it will replace. The replacement mechanism is similar in *M. cephalus*, *M. rammelsbergi*, and *Xenomugil thoburni* except that there are generally two rows of replacement teeth instead of one in these species (Fig. 3 C).

The replacement teeth of *Chaenomugil proboscideus* are remarkable in that they are arranged in many series, the cross-rows of which double back so that in cross-section they appear like sinuous chains of 30 or so teeth in different stages of development. The 7 or so terminal rows are functional teeth; the first few rows are pockets or alveoli in the gum in which the replacement buds will develop (Fig. 3 D). As a replacement tooth grows posteroventrad to become incorporated in the first functional row, it acquires the long bony base characteristic of a functional tooth (Figs. 3 D and 6 G). This base secures the tooth firmly in the gum. The terminal teeth of the chain are smaller than those in the middle functional rows. This is probably because they first grew into the functional position when the fish was smaller (Figs. 2 and 3 D). The point should be emphasized that the horizontal rows of teeth are not straight, but are wavy and that replacement may occur parallel to these rows instead of strictly posteroventrally (Fig. 2 and Pl. I B).

Replacement teeth in the secondary upper jaw rows are generally directly above the functional teeth (Fig. 3 A-C). Presumably, the teeth in the mandible are replaced in a similar manner to those in the upper jaw.

**GROWTH.**—The teeth of *Xenomugil thoburni* and *Chaenomugil proboscideus* (Fig. 7 A and C, respectively) appear to increase more rapidly in relative size with age than do those of the other species. *Mugil curema* exhibits a good deal of variation in the size of the primary teeth (Fig. 7 B). The largest specimens had relatively small teeth (Table I). This striking deviation from the tooth-body size relationships of the

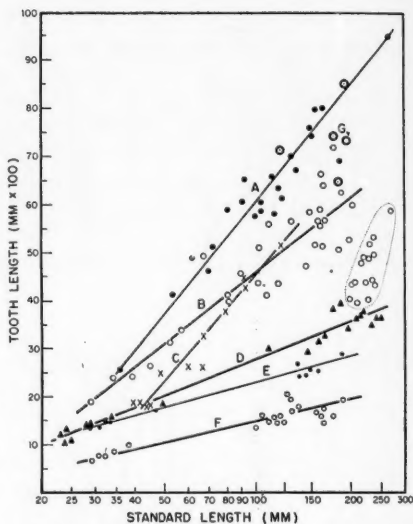


Fig. 7. Relation of tooth length to standard length in 6 species of mullets. A, *Xenomugil thoburni*; B, *Mugil curema*; C, *Chaenomugil proboscideus*; D, *Mugil cephalus*; E, *M. rammelsbergi*; F, *M. hospes*; G, *M. setosus*.

other species is graphically indicated by the group of points along the right hand margin of Figure 7 B that are encircled by the dotted line. These fish were all collected from Socorro Island and Cape San Lucas, Baja California. The disproportionately small teeth may be due either to racial variation or to the replacement of larger teeth by smaller ones in the large adults. A collection of young specimens (50 to 90 mm.) from near Balboa, Canal Zone had especially large teeth. These ranged from 0.59 to 0.74 per cent of the standard length.

No juvenile examined of any species had a complete complement of teeth. The number of teeth increases with growth of the fish (Table I). Furthermore, the premaxillary teeth appear before the mandibular teeth. Several younger juveniles, which were still in the pelagic stage, were examined. Specimens of *Xenomugil thoburni*, 12 to 35 mm. in standard length, were dip-netted at night under a light about a mile from shore in the Galápagos Islands. Their mouths and lips are disproportionately small, with minute needle-like teeth in the jaws (in the larger specimens, some of the teeth are curved and have yellow tips like the adults). None have teeth on the mandible, while only those



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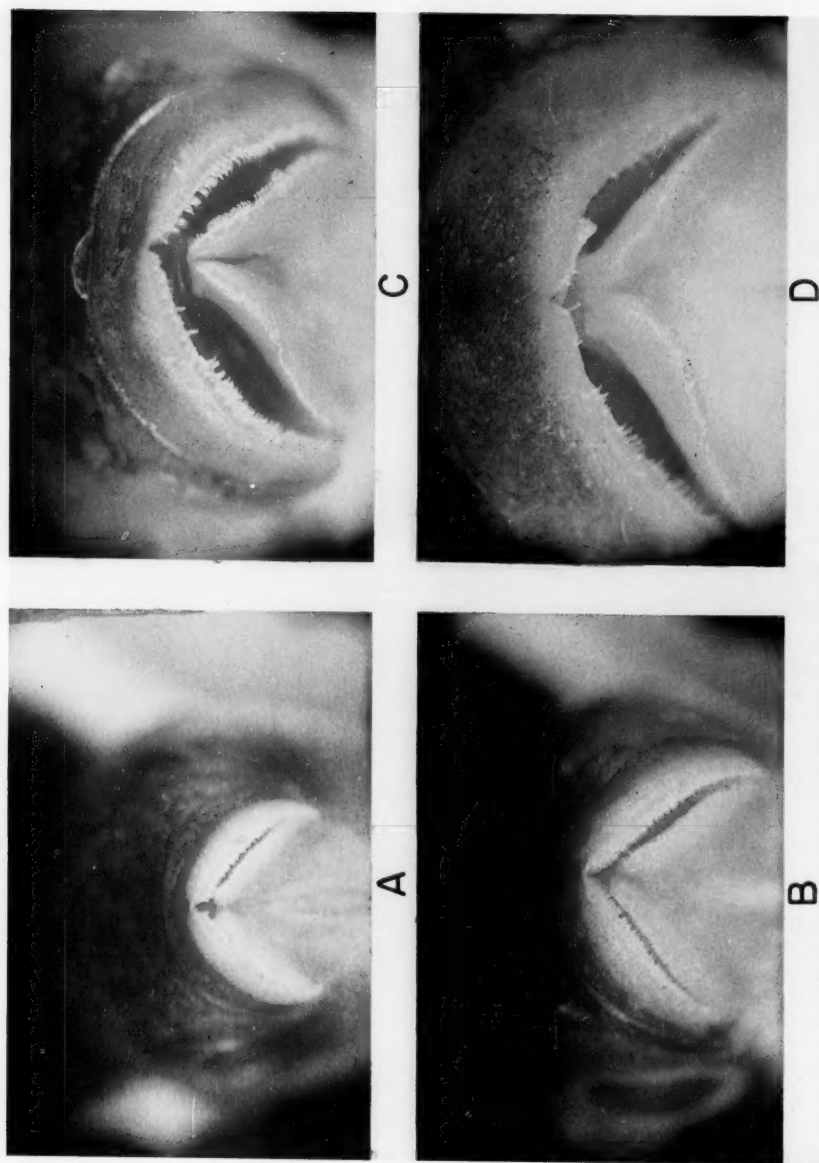


Plate II. Lips and teeth of *Xenomugil thoburni*, showing progressively greater turning under of the lower lip in the successive growth stages, represented by the standard lengths of A, 58 mm.; B, 78 mm.; C, 114 mm.; D, 157 mm. X6.7.

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TABLE II

INTRASPECIFIC VARIATION IN THE CONDITION OF THE SECONDARY UPPER-JAW ROW IN *Mugil curema*

Condition of secondary upper-jaw row	Number of specimens	
	Gulf of California	Socorro Island
No secondary row (or with fewer than 5 teeth).....	1	1
Partial secondary row (incomplete on both sides).....	1	2
Spotty (several wide gaps).....	2	2
Almost complete, hidden by gum...	4	4
Complete, easily visible.....	11	5
Complete, very densely packed.....	1	0
Totals.....	20	14

longer than 17 mm. have teeth in the upper jaw. Pelagic juveniles, tentatively identified as *Mugil hospes*, that were dip-netted off Costa Rica also have small mouths, toothless mandibles and minute teeth. Small pelagic juveniles of *Mugil rammelsbergi* and *Chaenomugil proboscideus* have characteristic bifid teeth in both jaws. The larger juvenile stages (longer than 25 to 35 mm.) of all species except *Chaenomugil proboscideus* have teeth forming only near the symphysis of the lower jaw. The teeth of these larger juveniles are disproportionately large (Table I).

In *M. curema* both the number and size of the secondary teeth vary between rather wide limits intraspecifically and even among the individuals within a single collection (Tables I and II).

In both *Chaenomugil proboscideus* and *Xenomugil thoburni* the lower lip becomes folded under, so that the teeth are directed either parallel with the horizontal axis of the body or obliquely downward (Pls. I B and II D). In the young of *Xenomugil* the lower lip is normal; the turning under is first apparent in individuals 60 to 100 mm. in standard length (Pl. II).

#### INTERSPECIFIC DIFFERENCES

The diagnostic tooth characters and geographical ranges for all the eastern Pacific Mugilinae except *M. peruanus*, which was not examined, are summarized by the following analytical key. These diagnoses may not gen-

erally apply to the smaller juveniles (see section under growth), some of which are pelagic and occur at some distance offshore. The genera and species groups can easily be diagnosed by tooth characters. The species of the *Mugil curema* group (*curema*, *selosus*, and *hospes*) have only simple teeth in the jaws, while those of the *M. cephalus* group (*cephalus* and *rammelsbergi*) have mostly bifid teeth (*M. cephalus* has a primary row of simple teeth in front of a secondary row of bifid teeth). Both *Xenomugil thoburni* and *Chaenomugil proboscideus* have the mandibular teeth directed downward in the adults. In both form and arrangement the peculiar bifid teeth of *Chaenomugil* are very different from any of the other species studied.

#### ANALYSIS, BASED ON DENTITION, OF THE GENERA AND SPECIES OF THE MUGILINAE OF THE EASTERN PACIFIC

- 1a. Upper lip not wide and thick; lower lip normal in all growth stages (Pl. III). Area of gum behind primary teeth in upper jaw not especially wide or, if wide, crowded with bifid teeth (Fig. 1 A and C-F). Teeth in jaws, when bifid, never shaped like claw crowbars with long bases (Fig. 6 B-F). Secondary teeth in upper jaw bifid (Fig. 6 B-F), in definite rows or bands (Fig. 1 A and C-F), already developed in the larger juveniles, except in *M. hospes*, which has very minute secondary teeth only in the adults (Figs. 1 E and 6 C) (*Mugil*).... 2
- 1b. Upper lip wide and thick; lower lip turned under (*Xenomugil*—adults, *Chaenomugil*—all stages) so that the mandibular teeth are directed downward (Pls. I B and II). Area of gum behind primary teeth especially wide, with or without relatively few scattered teeth (Figs. 1 B and 2). Teeth in jaws, when bifid, shaped like claw crowbars with long bases (Fig. 6 G). Secondary teeth in upper jaw either lacking (Fig. 2) or simple and developed, scatteringly, only in the larger half-grown and adult specimens (Fig. 1 B)..... 6
- 2a. Secondary teeth always simple (Fig. 6 B-C and E), and in uniserial rows or scattered behind the primary row (Fig. 1 A and D-E), never present in lower jaw (these teeth may be absent in juvenile and half-grown specimens). Primary teeth always simple (Fig. 6 B-C and E). (*Mugil curema* group)..... 3
- 2b. Secondary teeth always bifid (Fig. 6 D and F), in broad bands (narrow in juveniles) (Fig. 1 C and F), present in the upper jaws of all stages, and in the lower jaw of adults. Primary teeth simple or bifid (Fig. 6 D and F). (*Mugil cephalus* group)..... 5
- 3a. Primary teeth moderate to large, with yellow apical tips (Table I; Figs. 6 B, 6 E, 7 B, and 7 G); close-set or moderately spaced in adults (Fig. 1 A and D). Secondary teeth numerous, probably present in all stages except the smaller juveniles; typically more than 30 in adults, and moderate to large in size (Table 1).

- Lips moderate (Pl. III A-B). Area of gum behind primary row of upper jaw moderate in width (Fig. 1 A and D)..... 4
- 3b. Primary teeth minute, only 0.2 to 0.5 as long as those of *M. setosus* and *M. curema* (Table I; Figs. 6 C and 7 F), without yellow tips (although a suture delimits the tip); widely spaced in adults (Fig. 1 E). Secondary teeth present only in the larger adults (longer than 160 mm.); in a single row comprising only 2 to 30 almost microscopic teeth (Table I). Lips narrow (Pl. III C). Area of gum behind primary row of upper jaw narrow (Fig. 1 E). West coast of México to northern South America..... *Mugil hospes* Jordan and Culver
- 4a. Primary teeth in upper jaw moderate in size (Table I; Figs. 6 E and 7 B), not very densely packed (in adults frequent spaces in row are 1 to 4 times as wide as a tooth). Generally, no teeth (occasionally one or two) scattered between secondary and primary rows (Fig. 1 A). Mandibular teeth usually 0.6 to 0.8 times as long as the primary upper-jaw teeth, in adults, but 0.4 to 0.5 times as long in juveniles (Table I and Fig. 6 E). Area of gum behind primary row of upper jaw narrower (Fig. 1 A). West coast of México (including the southern part of Baja California) to northern South America, Socorro Is..... *Mugil curema* Valenciennes
- 4b. Primary teeth in upper jaw large (Table I; Figs. 6 B and 7 G), densely packed. Teeth of intermediate size scattered between a secondary row of small teeth and the primary row of large teeth (Fig. 1 D); these intervening teeth fewer in smaller adults (118-174 mm.). Mandibular teeth generally 0.4 to 0.55 times as long as primary upper-jaw teeth (Table I). Area of gum behind primary row of upper jaw moderately wide (Fig. 1 D). Clarion Island in the Revilla Gigedo Group
- Mugil setosus* Gilbert
- 5a. Teeth in primary row of each jaw simple (Fig. 6 F), or at most a few bifid at ends of jaw in large adults; hiatus between this row and secondary band wide; area of gum behind primary rows not especially wide. Secondary teeth not densely packed (Fig. 1 C); those in upper jaw about 0.45 to 0.6 times as long as primary teeth (Table I and Fig. 6 F). Secondary band in upper jaw comprising about 3 to 4 rows in adults and one row in juveniles (shorter than 34 mm.). Secondary mandibular band present only in adults, comprising 1 to 3 rows. Southern California to northern South America (probably not insular)..... *Mugil cephalus* Linnaeus
- 5b. Teeth in primary rows of each jaw all bifid (Fig. 6 D); hiatus between this row and the secondary band narrow; area of gum behind primary row especially wide, to accommodate broad secondary bands. Secondary teeth densely packed (Fig. 1 F); those in upper jaw about 0.6 to 0.7 times as long as primary teeth (Table I and Fig. 6 D). Secondary band in upper jaw comprising about 12 to 13 rows in adults, and 1 to 3 rows in juveniles (shorter than 47 mm.). Secondary mandibular band developed in all stages and similar to upper-jaw band. Coast of Perú and nearby islands, Galápagos Islands..... *Mugil rammelsbergi* Tschudi (based on Galápagos specimens)
- 6a. Teeth in each jaw simple and without long

bases (Fig. 6 A). Upper-jaw teeth of adults in 2 series, one uniserial row of larger teeth in front of scattered minute teeth (Fig. 1 B); only primary teeth in juvenile and some half-grown specimens. Lower lip turned under only in adults. Galápagos Islands, Perú, Panamá Bay

- Xenomugil thoburni* (Jordan and Starks)
- 6b. Teeth in each jaw bifid, shaped like minute claw crowbars with long thin translucent bony bases, 2.5 to 3.5 times as long as the overt tooth (Fig. 6 G). Teeth in each jaw in broad bands comprising 6 to 7 rows in adults and 2 to 5 rows in juveniles (Fig. 2). No secondary teeth in any growth stage. Lower lip turned under in all stages. West coast of Middle America and offshore islands, Socorro Island
- Chaenomugil proboscideus* (Günther)

#### PHARYNGEAL TEETH

The eastern Pacific Mugilinae have pharyngeal filtering devices consisting of gill rakers and toothed pads, which form the posterior roof of the pharynx. These resemble the pharyngeal mechanisms described by Al-Hussaini (1947), Pillay (1953), and Thomson (1954b), among others. The situation of the toothed pads is similar to that depicted in the Australian mullets by Thomson. The posterior gill rakers of the last pharyngeal arch form concavities on the floor of the pharynx in which fit the ventral convexities of the pads. Ingested material is filtered through the pharyngeal teeth, which span the narrow slit between the dorsal surface of the gill rakers and the ventral surface of the paired toothed pads.

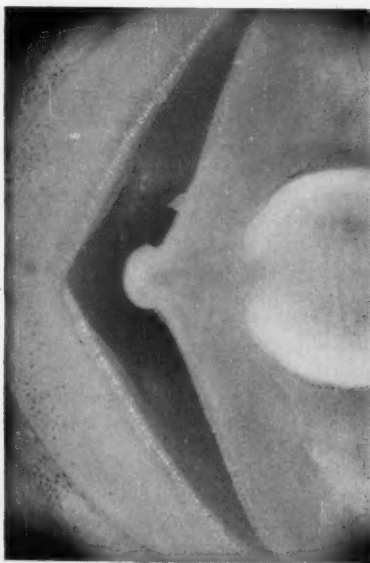
In most of the species small hirsute papillae, which, in some instances, represent unerupted tooth buds, lie among the functional pharyngeal teeth. In all of the species except *Chaenomugil proboscideus* each tooth-base is covered by a hirsute, fleshy sheath. These sheaths, in conjunction with the smaller papillae, probably increase the efficiency of the filter. The largest teeth are at the anterior edges of the pads; the teeth are progressively smaller towards the posterior edges. Compared with the primary teeth of the upper jaw, these teeth are larger (*Mugil hospes*, *M. curema*), about equal in size (*C. proboscideus*), or smaller (*M. curema*, *Xenomugil thoburni*, *M. rammelsbergi*). They are in distinct rows in *C. proboscideus*.

The pharyngeal teeth are simple in all the species except *C. proboscideus*, in which they are bifid with slightly scooped tips. With one exception (*Mugil rammelsbergi*) these teeth resemble those in the jaws though they are





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A



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Plate III. Lips and teeth of A, *Mugil curema*; B, *M. setulosus*; C, *M. hospes*; D, *M. cephalus*.  $\times 6.7$  (M. *setulosus*,  $\times 1.25$ ).

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more slender and curved. *M. rammelsbergi*, instead of having the pharyngeal teeth bifid like the oral teeth, have them simple, resembling those of *M. cephalus*. This possibly indicates a close relationship between these species.

The small pelagic juvenile mullets that were examined (*Xenomugil thoburni*, *Chaenomugil proboscideus*, and "*Mugil hospes*") have well-formed pharyngeal pads and teeth.

#### THE FEEDING HABITS OF MULLET

The adults of most mullet species are either vegetarians, which browse on minute epiphytes, or iliophagous, i.e. they stir up and gulp mouthfuls of bottom dirt and sand, expel the coarser granules, and digest the nutritive material off the mineral matter and non-nutritive detritus (an excellent survey of the pertinent literature on the food of mullets is given by Thomson, 1954b). The guts of the iliophagous mullets contain a high percentage of the finer mineral matter; the coarser material is probably removed by the pharyngeal filter (Al-Hussaini, 1947; Jacot, 1920; Pillay, 1953; Sarojini, 1951; Thomson, 1954b etc.). They feed by swimming head downward and protracting the premaxillaries to bring the mouth opening to a horizontal position, then shaking their heads over the bottom to facilitate ingestion of the surface mud layers (Hiatt, 1947). Observations by Conrad Limbaugh at Guaymas, Mexico demonstrate a tendency for the larger mullets, one foot or more in length, to feed by taking up and expelling mouthfuls of sand (this "spitting action" is described by Thomson, 1954b) and for the smaller 4 to 10 inch mullets to scrape algae off rocks.

That the juveniles feed on animal or plant plankton or on minute attached algae was born out by an examination of the gut contents of a collection of *Xenomugil* from the Galápagos Islands. The muscular crops of the young specimens (to 30 mm.) contained almost exclusively calanoid copepods of the planktonic genus *Acartia*, while all sizes of fish above 54 mm. had crops filled with filamentous algal bits, detritus, and littoral diatoms. The stomachs of specimens of lengths greater than 102 mm. contained bits of coral mixed with organic matter. In general the crops of *Mugil curema* held little else but diatoms and algal filaments.

#### DISCUSSION

Schultz (1946) assumed, "... that the most primitive mullet had undergone the least amount of specialization. Such a mullet should retain largely unmodified teeth in bands on jaws, vomer, and palatines." He further stated that, "The lips would not be specialized with a thin edge or with modified teeth and papillae." On these probable assumptions, the dentitions of both the *Mugil curema* and *M. cephalus* species groups combine primitive and specialized characters. Though the three species that constitute the *curema* group have simple unmodified teeth on the jaws, these teeth are seldom in bands and the vomer and palatines are toothless. The *cephalus* group also lacks vomerine and palatine teeth, but the bifid secondary teeth are in more or less broad bands. The specimens of *M. rammelsbergi* from the Galápagos Islands, which have only bifid teeth, may represent the ultimate step in a trend toward bifidity of all the teeth in the jaws. Generally, in *M. cephalus*, only the secondary teeth are bifid; however, in older specimens, there may be a few bifid primary teeth at the ends of the jaws.

The peculiar bifid teeth and downward-folded lower lip of *Chaenomugil proboscideus* and the downward-folded lower lip of *Xenomugil thoburni* suggest that these species are the most specialized. Though *Chaenomugil* has highly specialized teeth on the jaws, it probably exhibits a primitive feature in the development of teeth on the tongue. Thus, this genus may also combine, as many organisms do, primitive and specialized characters. The teeth of these two species and *M. rammelsbergi* are well-developed and are relatively remote from the jaw bone; consequently, the fibrous attachment strands are long. These conditions may have resulted from three separate evolutionary trends, since the dental patterns in the species differ widely. These species are not as widely distributed as *M. cephalus* and *M. curema* along the mainland, but they are the most numerous insular species. Perhaps *C. proboscideus*, *X. thoburni*, and *M. rammelsbergi* were once endemic island forms, which have secondarily invaded the mainland. Other hypotheses of origin, however, are not excluded.

The relatively small size of the teeth in the adults of some species of mullets is indicative

of a change-over from a juvenile predaceous or browsing eating habit to an adult ilio-phagous habit. The small mouths, toothless mandibles, and small teeth of some pelagic juveniles suggest a limited metamorphosis of the mouthparts to thicker lips and larger teeth concomitant to their movement into shallow, nearshore water. The minute secondary teeth may, in some cases, serve as gum supports.

Despite the fact that the teeth of mullets are small to minute, their shapes and arrangements were found to be useful taxonomic characters. Teeth are of particular value in the identification of the juvenile or querrimana stages.

#### SUMMARY

This comparative study of the tooth morphology, development, and adaptation in the marine mullets (Mugilinae) of the eastern Pacific has disclosed valuable interspecific differences. The Mugilinae in the eastern Pacific comprise 3 genera, 2 species groups, and 7 or 8 species.

Mullet teeth are usually arranged so that smaller secondary teeth are behind a uniserial row of larger primary teeth, but one species lacks secondary teeth and has a broad band of primary teeth.

The primary teeth in the upper jaw are attached to the premaxillary by fibrous strands, very remotely in some species. The secondary, smaller teeth in the upper jaw are loose in the gum and have no connection with the premaxillary. The mandibular teeth are correspondingly remote from the dentary and are connected with this bone by fibrous strands, which are usually longer than the corresponding annectant strands of the upper jaw.

Mullet teeth are generally minute. The simplest type is shaped like the end of an upholsterer's needle, that is, slightly flattened and curved inward at the tip. The more specialized teeth are bifid, and in *Chaenomugil* are shaped like the end of a claw crowbar. In general the teeth have yellow apical tips.

Replacement teeth are usually anterior to the bases of the primary teeth. These developing teeth are in one or more rows and, presumably, rotate posteriorly to fill the gaps left by their missing functional predecessors. The replacements for the secondary teeth subtend their functional counterparts.

The teeth of some species appear to increase more rapidly in relative size with age than do

those of others. The teeth of all the larger juveniles are disproportionately large. The few smaller pelagic juveniles examined had small mouths and very minute teeth; some had toothless mandibles. In two species, the lower lip turns under during development.

All the species have pharyngeal filtering devices consisting of gill rakers and toothed pads, which form the posterior roof of the pharynx.

It is generally agreed that mullets are mainly phytophagous, browsing on minute epiphytes. Although the adults of some species are ilio-phagous, the young are browsers or carnivores.

In dentition, both the *Mugil curema* and *M. cephalus* species groups combine primitive and specialized characters. The genera *Xenomugil* and *Chaenomugil* seem the most specialized. *Chaenomugil*, however, may have retained a primitive feature, teeth on the tongue. The dentition of mullets closely reflects their feeding habits.

#### ACKNOWLEDGEMENTS

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## Cyprinid Fishes of the Subgenus *Cyprinella* of *Notropis*

### I. Systematic Status of the Subgenus *Cyprinella*, with a Key to the Species Exclusive of the *lutrensis* - *ornatus* Complex

ROBERT H. GIBBS, JR.

THE large and diverse genus *Notropis* has long presented difficulties to the systematic ichthyologist. For many years this taxon was broken into a large number of components, each considered as a distinct, but often poorly characterized, genus. Gilbert (1885) and Jordan (1885) recognized the confusion resulting from this subdivision and united the many species in a single genus. This action has held until the present time, despite sporadic efforts (Jordan, 1929; Jordan, Evermann and Clark, 1930) to again split the genus.

Many workers are dubious concerning the recognition of subgenera within *Notropis*. While the relationships of many of the species are not yet clear, certain others form natural groups that should be recognized. One such group is the subgenus *Cyprinella* Girard. This paper redefines this subgenus, shows in a broad sense the interspecific relationships, and provides a key for the identification of the species exclusive of the *lutrensis*-*ornatus* complex.

This work is derived from a thesis presented to the faculty of Cornell University in partial fulfillment of the requirements for the degree of Doctor of Philosophy. Grateful appreciation is due to Dr. Edward C. Raney, under whose guidance the work was done, and to numerous others who have allowed me to examine speci-

mens or have contributed time and suggestions.

#### NOMENCLATURAL HISTORY

In spite of the rather obvious similarity of the species of the subgenus *Cyprinella*, the large number of genera to which they have been allocated in the past indicates that ichthyologists have not completely recognized their close interrelationship. Nor does the number of genera entirely show the confusion, for even generic composition was not stable, a given species often being moved indiscriminately from genus to genus. The characters used in dissecting the group have been superficial, many of them variable among individuals of the same species. The prime example of this is seen in the two genera *Moniana* and *Cyprinella*. In 1853, *Leuciscus lutrensis* and *L. bubalinus* were described by Baird and Girard. In 1856, *lutrensis* was placed by Girard in the genus *Moniana*, and *bubalina* in *Cyprinella*, and in 1876 these species were designated by Jordan and Copeland as type species of their respective genera. Not until 1929 were these two species shown by Hubbs and Ortensburger to be synonymous. The two genera had been based on the presence or absence of a tooth in the minor row. It is now well known

AUTHOR	GENUS OR SUBGENUS		1. LEUCISCUS	2. CODOMA	3. CYPRINELLA	4. HYPSILEPIS	5. PHOTOGENIS	6. HYDROPS	7. PLACIUS	8. MINNULUS	9. CLIOLO	10. LUTOLA	11. EROGALA	12. HUSSENIUS	13. NOTROPIS
BAIRD & GIRARD, 1853															
GIRARD, 1856															
COPE, 1864															
COPE, 1866															
COPE, 1867															
COPE, 1870															
JORDAN, 1876															
JORDAN & COPELAND, 1876															
JORDAN, 1877A															
JORDAN, 1877B															
JORDAN, 1877C															
JORDAN, 1878A															
JORDAN, 1878B															
JORDAN, 1878C															
JORDAN & BRAYTON, 1878															
JORDAN, 1879															
JORDAN, 1880															
HAY, 1881															
JORDAN, 1882															
JORDAN & GILBERT, 1883															
JORDAN, 1884															
JORDAN & MEER, 1885															
GILBERT, 1885															
JORDAN, 1885															
JORDAN, 1929															
JORDAN, EVERMANN & CLARK, 1930															
TOWLER, 1945															
HUBBS, 1955															

☒ GENUS USED      ☒ SUBGENUS USED IN NUMBERED GENUS  
☐ NOT USED      ☐ NOT MENTIONED: STATUS UNKNOWN

Fig. 1. Genera and subgenera in which species now included in the subgenus *Cyprinella* have been placed by previous authors.

that *lutrensis* not uncommonly has a tooth in the minor row, although normally this is lacking.

In addition to the presence or absence of the minor row of pharyngeal teeth, characters used in placing the species in different genera include the presence or absence of serrations on the teeth, the placement of the dorsal fin (whether slightly before or slightly behind the pelvic insertion), and peculiarities of coloration. All of these are known to vary individually, and the last may be dependent upon whether or not the specimens are in breeding condition.

It is not difficult to see, therefore, that by using such characters artificial subdivisions of the group might easily arise, and that a confusing array of arrangements could result. Figure 1 gives an indication of the haphazard past placement of species of *Cyprinella* in different genera and subgenera. It is evident that Jordan is the major perpetrator of these vacillations, and that the period from 1876 to 1885 would have been a difficult one from a nomenclatural standpoint for a student of this group.

Throughout the nomenclatural history of the species of *Cyprinella*, three Girardian

genera (1856) appear in more or less dilute form. These were based upon characters of the pharyngeal teeth:

A tooth in the minor row ..... *Cyprinella*  
 No teeth in the minor row  
   Teeth serrated ..... *Moniana*  
   Teeth not serrated ..... *Codoma*

Not until 1883, however, did Jordan and Gilbert reduce all the species to these three categories (as subgenera of *Clio*la), the only deviation being *Cyprinella cerostigma* Cope, which was purported to have 2,4-4,2 teeth and was included in *Minnulus*. In 1885, Jordan placed all the species in these three subgenera under the genus *Notropis*, thus giving an essentially modern arrangement. By 1929 he had apparently come to realize the unity of the group, and considered *Moniana* as a synonym of *Cyprinella*, although no mention was made of *Codoma*. He had united these two categories previously (Jordan, 1877a), but at that time various species were scattered in several additional genera. The Check List of Jordan, Evermann and Clark (1930) set the nomenclature of *Cyprinella* back fifty years by carving up the group grotesquely and by restoring the unwarranted and poorly characterized genus *Erogala*, a name used, as a genus or subgenus, in recent years.

There can be little doubt as to the fundamental relationship among the species considered in this study as the single subgenus *Cyprinella*. The superficiality of the presence or absence of a tooth in the minor row has recently been emphasized by Bailey and Gibbs (1956). It is here proposed, although perhaps it has been intimated by Jordan, that *Codoma*, including only the Mexican species *ornata* as far as known, be also included in *Cyprinella*. The type species of *Cyprinella* is *Leuciscus bubalinus* Baird and Girard (= *Notropis lutrensis* (B. & G.)), as designated by Jordan and Copeland (1876).

#### SYNONYMY

*Cyprinella*.—Girard, 1856: 196 (original description); Cope, 1864: 279; Cope, 1866: 370 (doubtful as to status); Cope, 1867: 157; Jordan and Copeland, 1876: 153 (type species *Leuciscus bubalinus* Baird and Girard); Jordan, 1877a: 78; Jordan, 1877b: 57; Jordan and Gilbert, 1877: 91, 100; Jordan, 1878b: 57; Jordan, 1878c: 410; Jordan and Gilbert, 1883: 177 (subgenus of *Clio*la); Jordan, 1884: 405; Jordan, 1885: 25



(subgenus of *Notropis*); Jordan and Meek, 1885: 474 (subgenus of *Cliola*); Jordan and Evermann, 1896a: 255 (subgenus of *Notropis*); Jordan and Evermann, 1896b: 273 (subgenus of *Notropis*); Jordan, 1899: 58 (subgenus of *Notropis*); Cockerell and Callaway, 1909: 190, 194 (scale characters); Jordan, 1910: 58 (subgenus of *Notropis*); Jordan, 1916: 58 (subgenus of *Notropis*); Jordan, 1929: 80; Jordan, Evermann and Clark, 1930: 130; Fowler, 1945: 27 (subgenus of *Notropis*).

*Codoma*.—Girard, 1856: 194 (original description); Jordan and Copeland, 1876: 147 (type species *Codoma ornata* Girard); Jordan, 1877a: 78 (in *Mimulus*); Jordan, 1877b: 58; Jordan and Gilbert, 1877: 91, 100; Jordan, 1878c: 410, 423; Jordan and Brayton, 1878: 20; Jordan, 1879: 111; Hay, 1881: 506 (to *Luxilus*); Jordan and Gilbert, 1883: 173 (subgenus of *Cliola*); Jordan, 1885: 24 (subgenus of *Notropis*); Jordan and Evermann, 1896a: 254 (subgenus of *Notropis*); Jordan and Evermann, 1896b: 270 (subgenus of *Notropis*); Jordan, Evermann and Clark, 1930: 143.

*Moniana*.—Girard, 1856: 199 (original description); Jordan and Copeland, 1876: 153 (type species *Leuciscus lutrensis* Baird and Girard); Jordan, 1877a: 78 (referred to *Cyprinella*); Jordan, 1877b: 57 (subgenus of *Cyprinella*); Jordan and Gilbert, 1877: 91, 100; Jordan, 1878c: 410 (subgenus of *Cyprinella*); Jordan and Gilbert, 1883: 173 (subgenus of *Cliola*); Jordan, 1885: 25 (subgenus of *Notropis*); Jordan and Evermann, 1896a: 254 (subgenus of *Notropis*); Jordan and Evermann, 1896b: 271 (subgenus of *Notropis*); Jordan, 1899: 57 (subgenus of *Notropis*); Cockerell and Callaway, 1909: 190, 194 (scale characters); Jordan, 1910: 57 (subgenus of *Notropis*); Jordan, 1916: 57 (subgenus of *Notropis*); Jordan, 1929: 80 (synonymized with *Cyprinella*); Jordan, Evermann and Clark, 1930: 131; Hubbs, 1955: 11 (subgenus of *Notropis*).

*Photogenis*.—Cope, 1866: 378 (original description); Cope, 1867: 162; Cope, 1870: 463; Jordan and Copeland, 1876: 154 (type species *Photogenis spilopterus* Cope); Jordan, 1877a: 80 (subgenus of *Mimulus*); Jordan, 1877b: 57; Jordan, 1877c: 336 (characters); Jordan and Gilbert, 1877: 94; Jordan, 1878c: 421 (subgenus of *Luxilus*); Jordan and Brayton, 1878: 18 (characters); Jordan, 1880: 292 (subgenus of *Hudsonius*).

*Erogala*.—Jordan and Brayton, 1878: 20 (original description; subgenus of *Codoma*; type species *Photogenis stigmaturus* Jordan); Jordan, 1878c: 423 (subgenus of *Codoma*); Jordan, Evermann and Clark, 1930: 129; Fowler, 1945: 28 (subgenus of *Notropis*); Hubbs, 1955: 11 (subgenus of *Notropis*).

#### SUBGENERIC DIAGNOSIS

While no single set of characters has been found that will identify every member of the subgenus *Cyprinella*, the general occurrence in the subgenus of most of the following characters is indicative of a common origin.

The exposed margins of the lateral scales are higher than wide and are outlined in black, appearing diamond-shaped; *Notropis leedsi*, *trichroistius*, and *callistius* are exceptions.

The last two or three dorsal membranes have a much heavier concentration of pigment than those preceding. Many forms have independently lost this tendency, viz. *xaenurus*, *callisema*, *callitaenia*, *leedsi*, *callistius*, and the *lutrensis-ornatus* complex.

Pharyngeal teeth number 1,4-4,1, the only exceptions being *N. leedsi*, *callisema*, some of the *lutrensis-ornatus* group, and *callitaenia* in part.

Predorsal circumferential scales number 13-2-11. *N. venustus* has 15-2-11, *N. callistius* and *N. analostanus chloristius* 11-2-11, and *caeruleus* 11-2-9.

Caudal peduncle scales number 7-2-5. Only *N. callistius* and *xaenurus* differ, having 7-2-7.

The breeding tubercles were originally arranged in parallel rows on the top of the head, notal ridge, and sides of the caudal peduncle. Some species have lost this characteristic, and have the head tubercles scattered, the notal tubercles small and scattered or absent, and those of the caudal peduncle usually absent or, in two forms, moderately large and scattered. In addition, there is a concentration of small tubercles on the snout, and a hiatus between these and the tubercles of the rest of the head. Only *N. galacturus* and *camurus* have the two areas connected.

The single major character found without known exception is the presence of a milky deposition in the fins of breeding males, although this is sometimes obscured by other coloration. In all species also, the dorsal and pelvic fins have eight rays, and the dorsal origin is placed just behind the insertion of the pelves.

Typical members of the subgenus *Cyprinella* may be distinguished from other species of *Notropis* by the combination of high scales with narrow, diamond-shaped outlines and dorsal fin membranes with melanophores present and most concentrated in the posterior membranes. A few other *Notropis* have somewhat diamond-shaped scales, but these are seldom much higher than wide. Even fewer have melanophores in the dorsal fin, and when these are present, the blotch in the posterior rays which is characteristic of *Cyprinella* is never formed. Species which do not show these two characters will be difficult to determine except during the breeding season, when males of all species accumulate a milky pigment in

TABLE I

INDEX OF SIMILARITY OF THE SPECIES OF *Cyprinella* EXCLUSIVE OF THE *lutrensis* COMPLEX. SEE TEXT FOR EXPLANATION

	callistius	leedsii	trichroistius	callisema	callitaenia	niveus	caeruleus	pyrrhomelas	xaenurus	analo-	chloristius	analo-	analo-	whipplei	spilopterus	venustus	galacturus	camurus
										staneus		staneus	staneus					
callistius	13	6.7	7.7	5.7	5.8	6.3	5.8	4.7	7.7	7.3	5.3	4.3	5.3	6.3	4.3	4.3	4.3	4.3
leedsii		13	7	11.3	10.8	8.7	5.5	7	6	5	5	6	4	4	4	4	4	4
trichroistius			13	5.3	5.8	8.7	7.5	9	8	9	9	8	9	6	8	8	8	8
callisema				13	11.8	9.7	6.8	7.3	6.3	6.3	6.3	7.3	5.3	5.3	5.3	5.3	5.3	5.3
callitaenia					13	10.5	7.7	7.8	6.8	7.2	7	7.8	6.2	6.2	6.2	6.2	6.2	6.2
niveus						13	8.8	8.7	7.7	9.3	9.3	8.3	6.3	6.3	6.3	6.3	6.3	6.3
caeruleus							13	7	6	9.5	8.5	7.5	9.5	9.5	7	6.5	6.5	6.5
pyrrhomelas								13	10	9	10	11	9	5	9	9	9	9
xaenurus									13	8	9	8	7	7	6	6	6	6
a. chloristius										13	11	10	10	9	8	8	8	8
a. analostanus											13	12	10	8	10	10	10	10
whipplei												13	9	7	11	11	11	11
spilopterus													13	11	8	8	8	8
venustus														13	6	6	6	6
galacturus																13	13	13
camurus																	13	13

their fins, particularly the dorsal and anal, which is strongly diagnostic. Also at this season, the presence in many species of *Cyprinella* of tubercles in parallel rows on the head, notal ridge, or caudal peduncle is a character found in no other *Notropis*. Those species which most closely approach the *Cyprinella* in size and robustness (*N. cornutus*, and *N. lythrurus* for example) usually have 2,4-4,2 teeth, while the species of *Cyprinella* apparently never have more than a single tooth in the minor row.

#### PHYLOGENY

Any discussion of the group characters of the subgenus *Cyprinella* must be accompanied by an analysis of its phylogenetic changes, for, as already stated, no single set of permanent characters is known to define the group so as to include all the related species.

As an aid to determination of the degree of relationship of the various species, an index of similarity has been formulated, which consists of assigning a value of from zero to one, to thirteen relatively constant characters. A value of one indicates that the two species being compared share the character in question. An index of thirteen, therefore, will be found if two species have all the characters in common. The

results of this procedure are shown in Table 1. The characters considered are as follows:

(1) Presence or absence of a notable darker concentration of pigment in the last two or three dorsal fin membranes. This was clear cut in all but *Notropis caeruleus*, which was always rated  $\frac{1}{2}$ , since it usually lacked pigment although breeding males closely approached the typical condition.

(2) Presence or absence of the narrow dark scale outlines which give the scales a diamond-shaped appearance. *Notropis trichroistius* showed a weak tendency to have one or two rows of diamond-shaped scales near the lateral line, but was considered as lacking in this character.

(3) Number of pharyngeal teeth. *Notropis callitaenia* tends to have a tooth missing in the minor row of one side and was rated  $\frac{1}{2}$ . Otherwise the count is either 1,4-4,1 or 4-4.

(4) Arrangement of breeding tubercles. Three areas were considered and rated at  $\frac{1}{2}$  each. It was possible to have the tubercles in linear rows, scattered, or absent on (a) top of head, (b) notal ridge, (c) caudal peduncle.

(5) Number of predorsal circumferential scales.

(6) Number of scales around the caudal peduncle.

(7) Number of anal rays.

(8) Configuration of mouth, whether inferior or otherwise.

(9) Color of dorsal and caudal fins in breeding males, whether red, yellow, or otherwise.

(10) Presence or absence of enlargement of dorsal fin in breeding males.

(11) Presence or absence of an intensely dark, narrow, lateral stripe.

(12) Presence or absence of a dark lateral blotch in breeding males.

(13) Presence or absence of depigmented areas at the base of the caudal fin.

The ideas presented here are based largely on the characters enumerated above and on an analysis of geographical distribution. Individual species or species groups will be discussed in somewhat more detail in later papers. This presentation, then, is an outline of the major conclusions. Some of the reasoning underlying these conclusions may serve to clarify the picture.

The distribution of the subgenus *Cyprinella* may be characterized roughly as radial. The Mississippi River and all its major and minor tributaries are the "hub", and in this entire system, four species are found. Two of these, *spilopterus* and *whipplei*, have ranges which include a large portion of the system. The remaining two, *galacturus* and *camurus*, are relatively restricted, the former to some Ozarkian streams and the Tennessee and Cumberland river systems (rarely in others), the latter to upper Arkansas River tributaries and smaller tributaries to the lower part of the Mississippi.

In a half circle about this "hub" are the rivers which flow into the Gulf of Mexico and the Atlantic Ocean. One species, *venustus*, is found in Gulf river systems from the Rio Grande in Texas to the Suwannee in northern Florida and Georgia. Outside of the *lutrensis-ornatus* group, it is the only species in Gulf systems west of the Mississippi and east to the Pascagoula River system. Beginning with the Mobile Bay drainage and continuing in a wide arc up the Atlantic coast as far as the Peedee River system in South and North Carolina, the major rivers are notable for their endemic or semi-endemic species of *Cyprinella*.

On the eastern Gulf, in addition to *venustus*,

three species are found in the Alabama-Tombigbee (Mobile Bay) system, and all are strictly endemic (*callistius*, *trichroistius*, *caeruleus*). In the Chattahoochee-Flint (Apalachicola) system, *callitaenia* is found.

On the Atlantic slope, in the Altamaha River system, *callisema* and *xaenurus* are endemic. On the Coastal Plain from the Ochlockonee River (Gulf drainage) north to the Savannah, is *leedsi*. From the Savannah, on the South Carolina border, to the Tar, in northern North Carolina, *niveus* has been taken. In the Santee and Peedee systems (North and South Carolina), *pyrrhomelas* is also an inhabitant. Thus essentially from Alabama to North Carolina, the major rivers tend to harbor their own, isolated species of *Cyprinella*.

Northward on the Atlantic slope from the Santee to the Hudson River and the Great Lakes, two species are found, *Notropis spilopterus*, which is one of the widespread forms in the "hub" and *N. analostanus*, which is extremely close to the other widespread "hub" form, *whipplei*. In this part of the range, endemism is no longer rampant. (A distinct subspecies of *analostanus* is found in the Santee system, with an intergrading population in the Peedee.)

My belief that the arrangement of breeding tubercles in rows is primitive and that scattered tubercles represent a modification of this arrangement is based on two facts. First, in those species which possess scattered tubercles, a pair of weak but definite head rows appears early in development, only to be obscured later by other, surrounding tubercles. This, in itself, does not prove that rows of tubercles could not have arisen by the suppression of development of the surrounding ones, but when the geographical evidence is considered, this seems less likely.

All species having tubercles in rows are peripheral, not "hub" systems. Four, possibly five species have the head tubercles in rows: *trichroistius* and *callistius* in the Alabama, *leedsi* in systems from the Ochlockonee north to the Savannah, *pyrrhomelas* in the Santee and Peedee, and possibly *xaenurus* in the Altamaha. The distribution of these endemic or semi-endemic species strongly suggests that they are relicts. Traces or rows on the notal ridge and/or caudal peduncle are found in *niveus*, *callisema*, and *callitaenia*, all peripheral

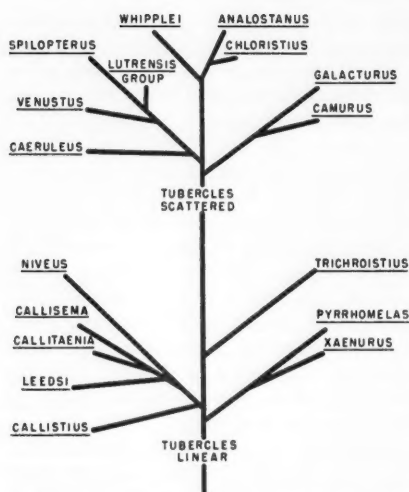


Fig. 2. Proposed phylogeny of the subgenus *Cyprinella*.

species. On the other hand, all of the presently highly successful, widespread species display scattered tubercles.

If the radiation from a "hub" stock, which originally had rowed tubercles but later had this condition modified to a scattered arrangement is not held as plausible, then several alternatives must be considered, all of which are less satisfying.

Simplest, but least probable, would be a multiple independent origin of rowed tubercles. This will not be considered further.

Perhaps early in the history of the subgenus, two basic stocks were isolated. One, in the Mississippi Valley, originated a line having scattered tubercles. The other, either in a Gulf drainage or on the Atlantic slope, developed rowed tubercles. The dispersal of the group with rowed tubercles from the Alabama to the Peedee would have required much lateral stream capture, since all but one of the species are upland forms. This, in itself, is not overly difficult to picture to some extent, and indeed, I have postulated it for one group of species (the *niveus* line, see Fig. 2). The origin and lateral dispersal of three other species within this framework, however, presents what seem to be unresolvable difficulties. Since all but one of the species with rowed tubercles are upland forms and all are quite mobile, it is

unlikely that populations in any single river system would have been segregated so as to allow ecological speciation. The only other alternative would be for stocks to have differentiated while isolated in one river system and then for the original species to have reinvaded from a neighboring system, often again to differentiate on the species level. The redistribution of these now would require still further lateral stream captures. This all would require much time and draws too heavily on lateral stream capture as an explanation. One of the major reasons for not considering this hypothesis to be as plausible as that which is being propounded, is that headwater captures between "hub" and peripheral systems must have been more frequent than lateral captures. Both types of capture have been fairly common (see, for example, Thompson, 1939), but the well-recognized westward migration of the Appalachian divide makes headwater piracy (with the Tennessee River as donor) a very likely method of species transfer. Furthermore, when probable relationships of the species are considered from a morphological point of view, the explanation of their distribution becomes extremely difficult by any other means. Any other possibilities must be derivatives of the three which have been presented.

The following phylogenetic interpretation is therefore, based on two assumptions: that rows of tubercles are primitive, and that the Mississippi Valley is the original center of radiation.

The basic characters of the subgenus, which were presumably present in the ancestral stock, are: (1) diamond-shaped scales, (2) last two dorsal membranes considerably more darkly pigmented than the more anterior ones, (3) a terminal mouth, (4) 1,4-4,1 teeth, (5) 13-2-11 predorsal circumferential scales, (6) 7-2-5 caudal peduncle scales, and (7) breeding tubercles arranged in linear rows on top of head, on notal ridge, and on sides of caudal peduncle.

The ancestral form was probably widely distributed through the Tennessee River system, which is known to have kept its integrity through a relatively long period. Perhaps the same or a similar stock was found in other parts of the Mississippi Valley. By means of headwater piracy of and by the Tennessee, the river systems of the southeastern United States received stocks of *Cyprinella*.

One of these invasions gave rise to a major evolutionary line which developed an inferior mouth and the general appearance of a bottom-living form. This line, of which *Notropis niveus* is considered the nearest approach to the early stock, was dispersed through river systems from the Alabama and Tombigbee to the Tar. A population was early isolated in the Alabama or Tombigbee, and gave rise to *Notropis callistius*. The retention of the breeding tubercles in rows on the head and notal ridge is indicative of its early separation, and is about the only character which links it to *Cyprinella*, for *callistius* is by far the most divergent form in the subgenus. After the initial dispersal of the *niveus*-like form, the population which now occupies the Savannah River and systems to the north, *Notropis niveus*, retained its appearance, notably the dark posterior dorsal pigment and 1,4-4,1 teeth. South of the Savannah, perhaps in the Altamaha, the stock differentiated, with a tendency toward the loss of the tooth in the minor row and a change in the dorsal fin pigmentation so that the forward membranes were pigmented more heavily than the rear ones, or all were more or less equally pigmented. Before a change in the tubercle pattern had taken place, however, the diverging stock gave rise to a Coastal Plain derivative, *Notropis leedsii*, which now retains the linear arrangement of tubercles and has 4-4 teeth, but no longer has diamond-shaped scales. The remaining form later became split into two further portions. *Notropis callitaenia* in the Apalachicola has not carried the tooth reduction as far as *callisema* of the Altamaha, and usually has a tooth in the minor row of at least one pharyngeal arch, while *callisema* always lacks the minor row. Both of these species have apparently lost the linear arrangement of head tubercles, but have retained that of the notal ridge. *N. niveus* has retained the peduncle rows, but this has not been observed in *callisema* and *callitaenia*.

While the stocks just discussed were becoming established to the south, another transfer across the Appalachian divide was taking place to the north, giving rise to *Notropis pyrrhomelas* in the Santee or Peedee. The relationship of this species to *N. xanurus* of the Altamaha is close, but it is problematical whether the stock spread southward and was

wiped out in the Savannah, the two species then evolving in isolation, or whether there may have been a direct transfer to the Altamaha of a form the same as or similar to that which gave rise to *pyrrhomelas*. *N. xanurus* has the head tubercles less strongly in rows, which may be an independent development, or may be an indication that it is derived from a Tennessee stock which had differentiated slightly since the time when the Santee or Peedee capture took place. The fact that *pyrrhomelas* and *xanurus* are the only two species which have 10 or 11 anal rays suggests the origin of one from the other.

At least one other capture presumably took place between the Tennessee and the Alabama before the basic tubercle pattern had begun to be modified. This resulted in the speciation of *Notropis trichroistius*, which is rather divergent from the basic stock in lacking diamond-shaped scales and in having the darkest pigment on the two dorsal membranes preceding the last, instead of on the last two.

During the course of time, most of the basic characters of the group remained intact in the Tennessee River and Mississippi Valley populations, but the linear arrangement of tubercles was replaced by a scattered arrangement. The presence of weak rows on the head which are later obscured by other tubercles has been mentioned. The notal ridge shows no evidence of the original arrangement, and in many species these tubercles are extremely small or absent. Only *Notropis lutrensis* and western *N. spilopterus* still show any notable caudal peduncle tubercle development, and in these the arrangement is not linear.

There have been three major lines evolved from the later Mississippi Valley stocks.

*Notropis whipplei* probably developed in the Arkansas and Ouachita rivers or their vicinity and, judging from its present habitat, became adapted to rather warm, mainstream waters. It was easily dispersed across the Mississippi and crossed the Appalachian divide by stream capture to give rise in the ensuing isolation to *Notropis analostanus* on the Atlantic slope. The notal tubercles of this group are quite reduced in size, and there is no particular fin coloration in the breeding males.

Another common stock, possibly originating in the Tennessee basin, probably gave rise to



*Notropis galacturus* in the Tennessee, moved across the Mississippi to the Arkansas River, and speciated to become the present *N. camurus*. *N. galacturus* has more recently reinvaded the Ozark region. This group is marked by depigmented areas at the caudal base, by the presence of red pigment in the dorsal and caudal fins of breeding males, and by the continuity of the tubercles of head and snout.

*Notropis spilopterus* appears to have originated in, or at least been dispersed by, the now-extinct Teays River system (Janssen, 1953). This stock probably became established in other systems as well, including the Tennessee, where a capture with the Alabama may have resulted in the speciation of *Notropis caeruleus*, which at present is barely surviving. A portion of the stock also reached the Gulf coastal area, where it developed, among other characters, a tail spot, and the resultant species, *venustus*, has dispersed throughout the Gulf drainages and up the Mississippi. The presumed common origin of *spilopterus*, *venustus*, and *caeruleus* is based principally on the presence of yellow pigment in the fins of breeding males and the reduction of dorsal fin pigmentation; on the presence, in *spilopterus* and *venustus*, of a dusky lateral blotch in breeding males, which is normal in the latter, rare in the former; and on the comparatively large size of the notal tubercles in the same two species.

The *lutrensis-ornatus* group was presumably derived from the *spilopterus*-like common stock. Its southwesterly distribution argues strongly for an original isolation in Texas or elsewhere in the southwestern United States and consequent dispersal of the newly evolved form into Mexico, where further differentiation took place. No doubt the tendency for southwestern streams to form isolated pools at certain times has been a factor in the tremendous variability of this group, and dispersal has probably been aided by the characteristic sudden flooding of these streams. Relationship to *spilopterus* is indicated by the tubercle pattern, which is very similar in *lutrensis* and in *spilopterus* from Mississippi (other than Ohio River) drainages, and by a lack of concentrated pigment in the posterior dorsal rays. In the Arkansas River, *spilopterus* closely approaches *lutrensis* superficially, and there is a possibility that hybridization may occur there. The vivid

red color of the fins of breeding male *lutrensis* is evidence of distinctness, and, as a recognition character, may account for the usual lack of interbreeding with *spilopterus*. Of the group, only *ornatus* appears to have diverged to considerable degree. This species is entirely Mexican in distribution. These comments on the *lutrensis-ornatus* group must await corroboration by a more-detailed study, and should not be considered in quite the same light as those concerning the other *Cyprinella*, which are speculative, but less so.

A generalized phylogenetic tree of *Cyprinella* is shown in Figure 2.

KEY TO THE SPECIES OF *Cyprinella*  
EXCLUSIVE OF THE *Lutrensis-Ornatus*  
COMPLEX<sup>1</sup>

All proportional measurements are expressed as percent of standard length. The most common range of variation of these and of the meristic counts is recorded with the extremes included in parentheses, as (14)15-17(18). Circumferential counts are divided into number of scales above, in, and below the lateral line, as 13-2-11. All counts and measurements were made as described by Hubbs and Lagler (1947), except *postdorsal length*, which is the linear distance from dorsal origin to caudal base, and the distance from *dorsal origin to lateral line*, which is self-explanatory. All measurements were made on specimens between 50 and 60 mm. standard length.

- 1a. Anal rays 10 or 11; tubercles of breeding males in rows on notal ridge and caudal peduncle. . . . . 2
- 1b. Anal rays 8 or 9; tubercles of breeding males in rows or scattered. . . . . 3
- 2a. Caudal peduncle scales 7-2-7; lateral-line scales 38-39(40); body depth 22-24(26); dorsal origin to lateral line (13)14-15; upper jaw length (8)9; posterior margin of caudal fin not edged with black; tubercles on top of head in breeding males in rows or not. *Allamaha* system. . . . . *xaenus*
- 2b. Caudal peduncle scales 7-2-5; lateral-line scales (34)35-39; body depth (22)25-26(29); dorsal origin to lateral line (14)15-17(18); upper jaw length (8)9-10(11); posterior margin of caudal fin edged with black; tubercles of top of head in breeding males in rows. *Peedee* and *Santee* systems. . . . . *pyrrhomelas*
- 3a. Anal rays usually 8. . . . . 4
- 3b. Anal rays usually 9 (*venustus* from the upper

<sup>1</sup>Members of the *lutrensis-ornatus* complex are found in warmer streams of the Mississippi Valley as far north as Illinois and in affluents of the Gulf of Mexico in Texas. In using this key to identify specimens from these areas the possibility must be considered that this group may be involved.



- Chattahoochee system has 9 anal rays as often as 8, but is keyed from 3a)..... 12
- 4a. Scales appearing diamond-shaped; tubercles of breeding males in rows or scattered; dorsal fin with or without black blotch in posterior membranes; mouth terminal to inferior.... 6
- 4b. Scales not appearing diamond-shaped; tubercles in rows on top of head, notal ridge, and caudal peduncle in breeding males; no contrasting dark blotch in posterior dorsal membranes; mouth inferior..... 5
- 5a. Predorsal circumferential scales 11–2–11; caudal peduncle scales 7–2–7; lateral-line scales (37)38–40(41); dorsal origin to lateral line (12)13–14(15); no prominent lateral stripe present. *Alabama* and *Tombigbee* systems..... *callistius*
- 5b. Predorsal circumferential scales 13–2–11; caudal peduncle scales 7–2–5; lateral-line scales (35)36–37(39); dorsal origin to lateral line (13)14–17(18); prominent dark lateral stripe present. *Savannah*, *Ogeechee*, *Altamaha*, *Suwanee*, and *Ochlockonee* systems..... *leedsii*
- 6a. Predorsal circumferential scales above lateral line usually 11..... 7
- 6b. Predorsal circumferential scales above lateral line usually 13 or more..... 8
- 7a. Predorsal circumferential scales 11–2–9; body depth (19)21–22(23); caudal peduncle depth (9)10(11); dorsal origin to lateral line (12)14 (15); lateral blue to black stripe reaches to opercle. *Alabama* system..... *caeruleus*
- 7b. Predorsal circumferential scales 11–2–11; body depth 25–28(30); caudal peduncle depth (11)12(13); dorsal origin to lateral line (15)16–18; lateral blue to black stripe, when present, not reaching in front of dorsal origin. *Santee* system..... *analostanus chloristius*
- 8a. A prominent black caudal spot present which is considerably longer than wide and contrasts markedly with the lateral stripe. *Gulf coast drainages from Rio Grande to Suwanee*; *Mississippi affluents north to St. Francis system and southern Illinois*..... *venustus*
- 8b. Black caudal spot absent or obscure and about as wide as long, not contrasting markedly with the lateral stripe..... 9
- 9a. Pigment in dorsal membranes most dense posteriorly, usually forming a dark blotch which contrasts markedly with the membranes immediately anterior. Teeth 1, 4–4, 1..... 11
- 9b. Pigment in dorsal membranes usually absent or sparse, not forming a dark blotch posteriorly, often appearing more dense anteriorly. Teeth 4–4 to 1, 4–4, 1..... 10
- 10a. A tooth present in the minor row of at least one pharyngeal arch; a chain of macro-melanophores along ventral edge of lachrymal from eye to middle of upper jaw; a narrow caudal spot usually present, and darker than lateral stripe. *Apalachicola* and *Escambia* systems..... *callitaenia*
- 10b. Teeth 4–4; no chain of macro-melanophores along ventral edge of lachrymal; caudal spot not usually evident, or lighter than lateral stripe. *Altamaha* system..... *callisema*
- 11a. A prominent blue to black lateral stripe present; breeding males with tubercles in rows on notal ridge and lower caudal peduncle; mouth inferior, more or less horizontal; body depth (19)21–22(25); predorsal length usually the same as or slightly greater than postdorsal length. *Atlantic coast drainages from the Tar to the Savannah*..... *niveus*
- 11b. Lateral stripe, when present, diffuse, wide; breeding male with tubercles scattered on notal ridge, caudal peduncle; mouth terminal or subterminal, oblique; body depth (19)22–27(31); predorsal length usually greater than postdorsal length. *Widespread in the Mississippi and Ohio valleys, from the upper Arkansas and Gasconade rivers on the west and the Tennessee River on the east, north to and including the upper Mississippi River and Great Lakes, and on the Atlantic slope southward to the Potomac River, exclusive of New England*..... *spilopterus*
- 12a. Scales above lateral line not appearing diamond-shaped; a prominent dark lateral stripe and caudal spot present, these usually merging, but sometimes separate; tubercles of breeding males in rows on top of head, notal ridge, and lower caudal peduncle; pigment in posterior dorsal rays usually jet black, darkest on the two membranes preceding the last; dorsal in breeding males colored bright orange. *Alabama* system..... *trichroistius*
- 12b. Scales appearing diamond-shaped; usually no prominent lateral stripe present, and never a caudal spot; tubercles of breeding males scattered on head, notal ridge, and caudal peduncle; pigment on dorsal rays often dark, but seldom jet black, darkest on the last two membranes; dorsal in breeding males not orange, but may be red or without bright coloration..... 13
- 13a. Base of exposed caudal rays depigmented, resulting in either a pair of dorsal and ventral caudal "wrist" patches or a decolored band at base of caudal; dorsal fin red in breeding males; no hiatus between tubercles on top of head and snout in breeding males; two rows of tubercles on each chin ramus..... 14
- 13b. Base of exposed caudal rays normally pigmented; dorsal fin in breeding males without bright coloration; a hiatus between tubercles on top of head and snout in breeding males; usually one row of tubercles on each chin ramus..... 15
- 14a. White caudal area in a pair of dorsal and ventral "wrist" patches; lateral-line scales (38)39–41(43); body depth (19)20–23(25); caudal peduncle depth (9)10–11; dorsal origin to lateral line (12)13–15(17); head length (23)24–26(27); snout conical or subconical. *White (Ozarks), St. Francis, Tennessee, Cumberland, Kanawha, Santee, and Savannah* systems..... *galacturus*
- 14b. White caudal area in a single narrow patch along the width of the exposed base of the caudal rays; lateral-line scales (35)36–38(29); body depth 24–27(28); caudal peduncle depth 11–13; dorsal origin to lateral line (14)15–18; head length (25)26–28; snout blunt. *Upper Arkansas River and tributaries to the lower Mississippi in Mississippi*..... *camurus*
- 15a. Lateral-line scales (33)37–37(38); pectoral rays usually 13 or 14. *Atlantic slope drainages from the Hudson River south to the Peedee; Cayuga Lake, N. Y.*..... *analostanus analostanus*

- 15b. Lateral-line scales (36)37-38(40); pectoral rays usually 15, sometimes 14 or 16. *Mississippi River tributaries from the Red River north to just above the mouth of the Missouri; Ohio River tributaries east to the Scioto and Little Kanawha*.....whipplei

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## The Breeding Cycle of the South American Fish, *Jenynsia lineata*, in the Northern Hemisphere

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The study of reproductive cycles in teleost fishes began with the recognition that the cycles were associated with annual seasonal changes and that various phases of the cycles were more or less constant in terms of the seasons. It was natural, therefore, to seek for the elements that controlled the reproductive cycles in the environmental factors which changed most in the high latitudes during the annual cycles, namely temperature and light. Investigation was extended to the gross and microscopical changes in the morphology of the gonads, as they appeared to be associated with changes in temperature or light. Some of these studies emphasized purely morphological aspects while others were concerned with establishing bases for experimental work. Descriptions of morphological changes during gonadal cycles in various fishes are to be found in the works of Turner (1919), Craig-Bennett (1931), Mathews (1938), Bullough (1939), Merriman and Schedl (1941), Harrington (1950) and others.

There have been a number of experimental studies in which normal light or temperature or both have been altered with the objective of determining the roles of these two factors in the control of normal cycles. Barney and Anson (1921) pointed out that reproduction in *Gambusia* declined while seasonal temperature was still favorable for further reproduction. Craig-Bennett (1931) concluded that in the three spined stickleback temperature changes were important and that light was negligible. However, Rowan (1938) citing results of other investigators received through personal communications indicates that, in the same animal, early breeding has been secured at low temperatures by light manipulation. Burger (1939)

working on the spermatogenesis of *Fundulus* concurred in the opinion of Craig-Bennett. Hoover and Hubbard (1937) were able to produce early spawning in two species of trout by appropriate manipulation of day lengths. Mathews (1939b) found that the absence of light on the males of *Fundulus* for at least four weeks prior to the breeding season did not inhibit activation of the testes in animals which had been on a rising daylight curve for nearly three months before they were placed in the dark. Turner (1938) in a study of reproduction of *Brachyrhaphis episcopi* under natural conditions in the Panama Canal Zone came to the conclusion that light was an important factor in maintaining continuous reproduction. Merriam and Schedl (1941) studied the effect of different exposures to light under normal and low temperatures upon the gonads of both males and females of the four-spined stickleback, *Apeltes quadracus*. From their results they postulated that in the normal environment joint action of light and temperature were essential in bringing about full maturity but that the two factors act differentially in the two sexes. It appeared also that there was a differential susceptibility in different cell generations in spermatogenesis and oögenesis to the effects of low and normal temperatures and of different exposures to light. Bullough (1939, 1941) after subjecting males and females of the minnow *Phoxinus laevis* to alterations in light and temperature concluded that there is a normal inherited rhythm which may act independently but that seasonal changes in light and temperature render it more precise in the time of its action. He assumed that a pituitary mechanism was involved and that temperature as well as

light probably affected this mechanism. Harrington (1950) exposed the bridled shiner, *Notropis bifrenatus*, daily to 17 hours of daylight for a period of three months and then returned the treated specimens to exposures of normal seasonal daylight. The specimens were maintained at room temperatures. The treated specimens spawned three months in advance of the usual breeding season. The results provided presumptive evidence that light was required under normal conditions for completion of sexual maturity and that temperatures lower than room temperatures might prove suitable. Harrington (1956) was able to secure completion of the entire reproductive cycle in the Banded Sunfish, *Enneacanthus obesus*, in six weeks by exposing both males and females from Oct. 4 to Dec. 15 to a continuous day length of 15 hours and maintaining them at a summer temperature. Temperature had little effect upon spermatogenesis but oögenesis is definitely influenced by temperature changes. The experimental specimens not only matured their gametes but assumed breeding coloration and sexual behavior. Normal spawning occurred and living young were obtained.

Another method of approach to the problem of control of reproductive cycles has consisted of a study of the relations of pituitary hormones to gonadal cycles. Studies have involved ablation of the pituitary, implantation of pituitaries into normal immature fishes or into hypophysectomized fishes and the injection of pituitary extracts from the same or other species of fishes or from higher vertebrates. Houssay (1931) and others have demonstrated that saline suspensions of the pituitaries when injected into the peritoneal cavities of fishes produce accelerated reproductive cycles. Vivien (1938) hypophysectomized specimens of *Gobius paganellus* and found that there was a pronounced regression of both ovary and spermary. Hasler, Meyer and Field (1939) were able to produce early maturity in the trout by injecting them with extracts of pituitaries from the carp. Mathews (1940) working upon *Fundulus heteroclitus* found that implantation of adult pituitaries into immature specimens produced an early development of the gonads. Burger (1941) hypophysectomized mature males of *Fundulus heteroclitus* just after the breeding season. The males failed to initiate a new gonadal cycle but implantations of pitui-

taries of adult *Fundulus* into the hypophysectomized animals caused them to renew gonadal development.

Broad generalizations regarding the control of reproductive cycles in fishes are difficult to make since some fishes of different species living in the same environment differ radically in the time at which they mature and spawn. Different species apparently differ in the inherent mechanisms by which they respond to environmental controls. Rowan (1938), in an extensive review of the literature on light and seasonal reproduction in animals in general, is of the opinion that native fishes in the northern hemisphere show remarkable uniformity in their breeding cycles. The basic factor for fishes breeding in the spring appears to be length of day to which they are exposed, but low temperatures may have a retarding effect upon gonadal development. The theory for an operating mechanism is that light, falling upon the eye, stimulates the pituitary (presumably through nervous channels) which in turn induces gonadal development. The adaptation of an animal in its reproduction in a given latitude to the seasonal variations in day length at that latitude is important for the animal's survival. It might be added that the ability of a fish to extend its range would depend in part upon its ability to adapt its reproduction to changes in day length. It has been noted by commercial breeders of tropical and subtropical poeciliid fishes that reproduction tends to decline or cease altogether in northerly latitudes during the months of short day lengths when natural day length is not supplemented artificially. The explanation is not to be found in reduced food supply or temperature, for the decline occurs when these two factors are controlled so as to be favorable to reproduction.

It has occurred to the writer that a fish confined to a restricted range and adapted to the conditions of the temperate zone in one hemisphere might yield some interesting data if it were transferred suddenly to the temperate zone of the opposite hemisphere and a critical study made of its reproduction under controlled conditions. The reversing of the seasons would be a profound change, and the extent to which the strain of fishes could adapt to the change might furnish information on the inherent pattern of reproduction, on the flexibility of its inherent

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pattern and particularly the relation of day length to the reproductive cycle. The viviparous freshwater fish, *Jenynsia lineata*, is confined to a limited range in northern Argentina, Uruguay and southern Brazil. Through the good offices of Dr. Stillman Wright and friends in Buenos Aires a stock was collected and shipped by air to Evanston in September, 1952. The material was placed immediately under controlled conditions and the results obtained during a three year period are described in this paper.

#### MATERIALS AND METHODS

*Jenynsia lineata* is well adapted for culture in aquaria and for experimental work. When maintained in aquaria, adults will eat algae and other water plants. They will eat also tubifex worms, insect larvae, amphipods, shrimp meat and dried commercial foods. The young prefer live entomostraca but will thrive on finely ground commercial fish foods. Good results in reproduction are obtained with one pair of breeding specimens in a three to five gallon aquarium well stocked with aquatic plants. The young are sufficiently agile at birth to escape from the adults if plenty of vegetation is present. Five-gallon rearing tanks will accommodate 30 to 50 newly born young but more room will be required as the young fish grow. A temperature range of 50°F to 90° is tolerated well at all ages. Although *Jenynsia* is normally a freshwater fish it will live in full strength sea water for weeks.

Males mature before the females and, like the males of peociliid fishes, they are continually active in pursuing females at all seasons. Females normally mature during the first breeding season after their birth but maturity can be induced artificially about five months after birth by light manipulation. Females are about 30 mm. in standard length when they have their first broods. Several young are evacuated at intervals over a period of two or three days. A brood of 102 embryos has been obtained from a 95 mm. female but the number of individuals in a brood may be as few as 12. Broods are born at intervals of three to four weeks under ordinary conditions. The young are 9 to 11 mm. long at birth. Recognizable sexual differences in the young are found at four to five weeks after birth, when specimens measure 15 to 16 mm. Living sperm are retained in the ovary and a single

contact between male and female will suffice for the fertilization of several successive broods.

Ten large, gravid females were separated from the lot received from Buenos Aires September 23, 1952. One was sacrificed to determine brood size and eight others were divided into two groups. The first group of four was continued on the increasing day length which they had received in Buenos Aires while the other four were placed on a program of decreasing day length found at Evanston, Illinois. Changes in day length were made later. The exposure to light was manipulated by placing 150 watt Mazda bulbs 12 inches above the aquaria and placing program clocks in the circuits which would turn the lights off and on automatically at the appropriate intervals. Room temperature was maintained between 68° and 70°F. As broods were obtained from the females indicated above some of each brood were placed on a program of Evanston day length at room temperature. Sixty-seven specimens representing 11 different birth dates between October 24, 1952, and March 4, 1953, were observed and breeding records, including time of birth of first broods, total number in each brood, birth dates of broods and intervals in days between broods were recorded. Records were kept also of brood production by 20 selected females from the above 67 specimens during 1954. These specimens had been under a program of Evanston day length and room temperature since their birth and they were continued on the same program during 1954.

#### RESULTS

**REPRODUCTION OF FEMALES SHIPPED FROM ARGENTINA IN 1952.** All of the specimens received from Argentina in September had been on a rising day length since June 21. The four which constituted the first group and which were continued on Argentina day length received six months of rising day length and then three months of declining day length from December 21 to March 21. The four were then removed from exposure to Argentina day length on March 21 and were continued thereafter under Evanston day length (Table I and Fig. 1). They were subjected, in summary, to six months of rising day length, three months of declining day length and three months of rising day length before the regular decline of day length



TABLE I

BROOD PRODUCTION BY SPECIMENS RECEIVED FROM ARGENTINA AND CONTINUED ON ARGENTINE DAY LENGTH FROM SEPTEMBER 23 UNTIL MARCH 21, FOLLOWED BY EXPOSURE TO EVANSTON DAY LENGTH AFTER MARCH 21

	1st brood	2nd brood	3rd brood	4th brood	5th brood	6th brood	Died
Specimen 1	Oct. 24	Nov. 17	Jan. 16	Feb. 17	June 5	July 9	Sept. 10
No. of young	37	40	22	36	22	28	
Specimen 2	Oct. 26	Nov. 18	Dec. 28	—	—	—	Dec. 30
No. of young	102	40	30				
Specimen 3	Oct. 28	Nov. 22	Dec. 30	Feb. 2	May 18	—	June 17
No. of young	33	19	31	28	18		
Specimen 4	Oct. 28	Nov. 17	—	—	—	—	May 20
No. of young	27	30					

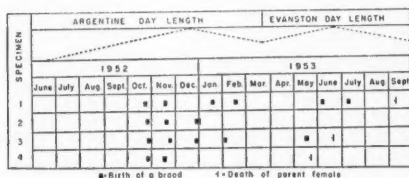


Fig. 1. Diagram illustrating relation of rising and declining day length to brood production in specimens shown in Table I. Symbols: ■ = birth of a brood; ⊥ = death of parent female.

beginning June 21. Food and temperature were kept at a fairly constant level. Consequently any deviation in reproductive history should be attributed to the influence of the modified day length. For the same reason the four specimens in group two put on Evanston day length on September 23 and continued on Evanston day length thereafter (Table II and Fig. 2) would deviate from the normal pattern of reproduction because of manipulation of day length. Brood production under natural conditions in the southern hemisphere begins on a rising day length and persists until February, three months after the shift from rising to declining day length.

The number of broods produced by each specimen of the first group of four together with the date of birth of each brood and the number of young in each brood is shown in Table I. The date of the death of the producing specimens is recorded also. The same data are recorded in Fig. 1 with the inclusion of the periods of rising and declining day length indicated at the top. Specimens continued on regular Argentina day length produced broods regularly from October 24 to February 17. Broods were somewhat larger

and the interval between broods was somewhat shorter during the early part of the period. The first two broods of each specimen were produced near the climax of a period of rising day length. The last brood was born about two months after the beginning of the period of declining day length.

Two months after the members of group one were taken off a declining day length (Mar. 21) and placed upon a program of rising day length the surviving members were producing broods again. The specimens either produced broods during May, June and July (late fall and winter months in Argentina during which reproduction does not occur) or died. The specimens were large and presumably were old females and it is possible that they were near the end of their life span, but it is likely that death was associated with the additional physiological requirements of a second reproductive period at a time when they normally would be reproductively inactive. In the single case (Specimen 1, Fig. 1) in which two broods were produced before the specimen died the interval between the two broods was approximately the same as a normal interval near the end of a regular breeding season.

The record of brood production in the second group, in which Evanston day length was imposed upon all 4 members on September 24, is shown in Table II. Brood production as associated with the changes in day length is illustrated in Fig. 2. It is apparent from the figure that under the conditions imposed brood production may continue from November until March, that brood production ceases from late March until May and that brood production is resumed at a period representing late fall and winter in

BROOD

Specimen  
No. of  
Specimen  
No. of  
Specimen  
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ARGENTINE DAY LENGTH	EVANSTON DAY LENGTH
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TABLE II

BROOD PRODUCTION BY SPECIMENS TRANSFERRED FROM ARGENTINE TO EVANSTON DAY LENGTH ON SEPTEMBER 23, 1952 AND CONTINUED ON EVANSTON DAY LENGTH THEREAFTER

	1st brood	2nd brood	3rd brood	4th brood	5th brood	6th brood	Died
Specimen 1	Nov. 17	Dec. 14	Jan. 18	June 11	July 12	—	Nov. 8
No. of young	33	34	28	22	21	—	—
Specimen 2	Nov. 21	Jan. 1	Feb. 16	May 20	—	—	June 10
No. of young	28	32	22	24	—	—	—
Specimen 3	Dec. 8	Jan. 12	Feb. 13	Mar. 18	June 3	—	June 13
No. of young	36	28	31	24	21	—	—
Specimen 4	Jan. 18	Feb. 22	May 29	—	—	—	June 7
No. of young	35	28	22	—	—	—	—

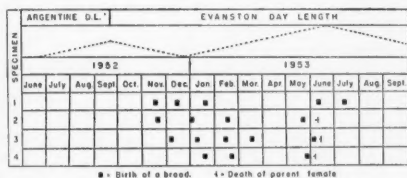


Figure 2. Diagram illustrating relation of rising and declining day length to brood production in specimens shown in Table II. Symbols: ■ = birth of a brood; ■ = death of parent female.

Argentina and that specimens may die during this period of induced reproduction. The interval between broods during this period remains approximately the same as that of reproduction in normal seasons.

A comparison of brood production in the two groups treated differently only in the exposure to different day lengths reveals a similarity in the general pattern in some regards. Each group produced broods of approximately equal number and size. Both began reproducing a second time at approximately the same date when subjected to a rising day length at a season which was not normal for them. The members of both groups were unable to survive long after the second reproductive season had started. The principal differences in the reproductive behavior of the two groups appears in the delay of production of the first cluster of broods by group two and the shorter rest period between the first and second waves of reproduction in group two. The similarities may be ascribed to fixed inherent reproductive characteristics while the points of difference are associated with inherent characters that are more flexible and respond more easily to environ-

mental changes. Postulates concerning the similarities and differences will be presented in the discussion.

REPRODUCTION BY YOUNG BORN IN FIRST SEASON IN EVANSTON IN 1953. As broods were produced by the females shipped from Argentina some members of each brood were set aside, placed on Evanston day length exposure and a record kept of the reproductive history of each specimen. The records include the history of 67 specimens selected from 11 broods born between October 24 and March 4 (Fig. 3 and Table III). Under natural conditions in the southern hemisphere these specimens would have been subjected after their birth to a declining day length for six months and to fall and winter temperatures before spawning. They would have bred ordinarily in the southern hemisphere in the spring following a period of rising temperature and rising day length. Under the controlled conditions in the northern hemisphere they were subjected after birth to no changes in temperature. Those born between October 24 and December 10 lived for a short period on declining day length and then to six months of increasing day length. Those born between December 30 and February 4 lived in a period of increasing day length (till June 21) and then in a period of declining day length. The total amount of information obtained is too voluminous to be presented in tabular form but averages were obtained for the members used of each of the eleven broods; they are shown in Table III. The table contains the birth dates of the breeding specimens, the interval in days between birth and the production of the first brood, the birth dates of the first, second, third and fourth broods and the interval in days between each brood. The information is presented graphically

TABLE III

THE COLUMN ON THE LEFT INDICATES THE BIRTH DATES OF 11 BROODS PRODUCED BY FEMALES SHIPPED FROM ARGENTINA DURING THE BREEDING SEASON

The members of the 11 broods were maintained under Evanston day length. The times required for maturity and first brood production by the members are indicated in columns 2 and 3. Further brood production, intervals between broods and cessation of brood production are shown in other columns.

Date of birth	Average interval in days to first brood	Birth dates of first brood	Average interval between first and second broods	Birth dates of second brood	Average interval between first and second broods	Birth dates of third brood	Average interval between second and third broods	Birth dates of fourth brood
Oct. 24.....	222.2	6/1-6/4	25.4	6/26-6/30	23.2	7/20-7/25	24	8/16
Oct. 26.....	225.0	6/6-6/9	25.2	6/30/7/2	22.7	7/20/7/27	24.3	8/13-8/19
Oct. 28.....	225.6	6/9-6/14	25.2	7/5-7/8	25.7	7/26-8/6	27	8/24
Nov. 2.....	227.5	6/16-6/19	20.2	7/6-7/10	24.2	7/30-8/3	—	—
Nov. 14.....	218.3	6/20-6/22	23.3	7/13-7/15	23.0	8/3-8/10	—	—
Dec. 10.....	200.15	6/23-6/30	22.0	7/17/7/25	23.8	8/7-8/20	—	—
Dec. 30.....	194.6	7/2-7/3	23.0	7/24-7/26	25.0	8/16-8/23	—	—
Jan. 14.....	178.1	7/10-7/13	25.4	8/2-8/9	23.0	8/24	—	—
Feb. 1.....	165.7	7/14-7/20	30	8/13	—	—	—	—
Feb. 6.....	165.8	7/21-7/23	—	—	—	—	—	—
Mar. 3.....	162.8	8/12-8/23	—	—	—	—	—	—

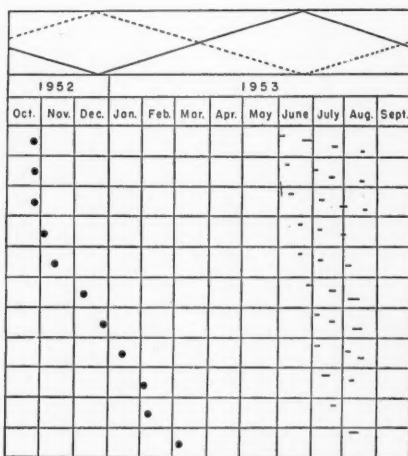


Fig. 3. Diagram illustrating relation of rising and declining day length to maturity and brood production in specimens shown in Table III. The symbol ● indicates the birth dates of broods produced by females received from Argentina. The reproductive records of the members of each dated brood is indicated by short lines at the right. Each line indicates a brood. The length of each short line indicates the span of time during which the members of the dated broods were producing broods themselves. Solid line above indicates increase and decrease in northern hemisphere day length; broken line for southern hemisphere.

in Fig. 3. The birth dates of the breeding individuals together with the birthdates of their offspring are shown in relation to Argentina and Evanston day length.

The facts which are most obvious from an examination of Table III and Fig. 3 are as follows: (1) All broods are produced during June, July and August. These are the late fall and winter months in Argentina during which there would be no reproduction in the natural habitat. (2) In the group born on March 4 maturity was attained and a brood of young was produced in slightly over five months while those born on October 24 required more than seven months to become mature and produce a brood. In other words, there was a steady decline in the time required for maturity between October 24 and March 4. (3) All reproduction ceased abruptly near the end of August regardless of the number of broods which had been produced and the date on which the parents became mature. (4) Once brood production was begun the interval in days between broods was approximately the same, mostly 22 to 25 days, in all specimens. (5) Since temperature was relatively constant during the period of observation and since during this time the innate capacity to become mature and to produce a brood in about five months was demonstrated, some factor other than tem-

perature and maturity must be invoked to account for brood production at seven months by specimens born in late October. (6) Since the specimens born early produced four broods and those born late produced only one brood before cessation of brood production and since cessation in all occurred at approximately the same date the cause for cessation would be an environmental one associated with the time of cessation rather than an inherent factor associated with quantitative production of a specified number of broods in a season. (7) The only environmental factor which can be associated with the cessation of breeding is the change from increasing to declining day length which occurs two months before the cessation of breeding. If the pituitary stimulation necessary to maturation and growth of eggs required a continually increasing day length the essential factor in the stimulation of the pituitary would be lacking when day length began to decrease. It would be assumed that about 60 days of stimulation would be required beyond a susceptible and critical stage in maturation for a period of maturation and gestation.

**PRODUCTION OF YOUNG IN 1954.** Twenty specimens of the 11 groups which produced young in June, July and August of 1953 were observed again in 1954. Each produced from four to six broods but the time of brood production was not concentrated in June, July and August as it was in 1953 (Fig. 3). Brood production began in late March and terminated in August. This period would be fall and winter in the southern hemisphere. Some of the young produced between June and August of 1953 were observed also. They produced young in the late spring and early summer of 1954.

It is apparent that these individuals of two different generations were adapting their reproduction to spring and summer conditions of the northern hemisphere although the stock from which they were derived had produced young in the spring and summer of the southern hemisphere. Keeping the specimens under nearly constant room temperatures instead of the extremes of temperature which occur in nature has been responsible probably for earlier and slightly longer reproductive periods.

#### DISCUSSION

The statements of Rowan (1938) should be recalled at this point that adaptation of an animal in its reproductive peculiarities to the day length at a certain latitude is important for its survival—that the basic factor for native fishes breeding in spring in the northern hemisphere is day length although low temperatures may retard reproductive activity—and that the operating mechanism is light falling upon the eye and stimulating the pituitary through nervous channels, the pituitary hormone in turn inducing gonadal development. It would appear that all of these points are applicable in the case of *Jenynsia*. This fish is adapted in its inherent reproductive mechanism to the particular conditions found within its distributional range. Similar conditions as regards day length and temperature are found in the northern hemisphere. The same sequence of seasons is found in the northern hemisphere. It is not surprising therefore that this southern temperate zone fish can adapt itself easily to northern temperate zone conditions. An interesting question arises here regarding reproduction in tropical habitats where temperature fluctuates little and day length is least changeable. In *Brachyrhaphis episcopi* it has been shown (Turner, 1938) that this ovo-viviparous fish reproduces at about the same rate the year round. If day-length is an important factor to which its reproductive activity has become fixed then it might be expected that transfer to the day length of the temperate zones would be deleterious. This could be tested experimentally. If, on the other hand, *Brachyrhaphis* exists in its limited range because of factors other than day length or temperature or both, the degree of its inherent flexibility to adapt to changes in day length and temperature could be demonstrated experimentally.

The present study of *Jenynsia* is concerned not so much with the fact that this southern hemisphere fish can breed in the northern hemisphere as it is with the reproductive history of fishes which are breeding as adults or are born under conditions of day length and temperature in one hemisphere and then are shifted suddenly and continue to live in terms of the day length of the opposite hemisphere. The degree of flexibility of its inherent reproductive mechanism

is demonstrated to some extent. Also the effects of altered day length and temperature upon the normal mechanism become apparent.

The effects of altering day length and temperature are shown in Figs. 1, 2 and 3. The left half of Fig. 1 represents the latter part of a reproductive sequence under conditions which are normal for Argentina day length but altered as to conditions of temperature to the extent that continuous room temperature differs from seasonal temperature changes in the natural habitat. The substitution of declining day length for increasing day length in mature breeding specimens (left half of Fig. 2) has the effect of postponing brood production but not of reducing the total number of broods. The substitution of a rising day length for a normal declining day length brings on a second period of brood production which is out of season (right halves of Figs. 1 and 2). Young are born normally in the spring and early summer in the southern hemisphere and then are exposed to a period of declining day during the winter. They become mature and breed the next spring on a rising day length. By exposing them to northern hemisphere day length (Fig. 3) from the time of their birth they may be induced to breed during the months of the early spring and summer of the northern hemisphere and to terminate their breeding at a time in advance of the breeding season of the southern hemisphere. Thus, by substitution of room temperature for the declining temperature of their normal environment and an increasing day length for a declining day length early maturity and breeding are induced. By a substitution of a declining day length for a rising day length cessation of reproduction is induced. The lack of stimulation normally found in a rising day length rather than a depressing effect of declining day length probably is responsible for the cessation of breeding.

No experimental work has been done in *Jenynsia* as yet such as extirpation of the pituitary, injection of pituitary extracts or implantation of pituitary to investigate the role of the pituitary in the chain of events between stimulation of the eyes by light and brood production, but it is assumed tentatively that the mechanism described by Rowan operates here. In mature specimens a shift from decreasing to

increasing day length brings on brood production (Fig. 1) in about two months at room temperature even though the induced brood production is out of season. If a period of 22 to 27 days is allowed for a gestation period, it may be assumed that a little more than a month of pituitary stimulation by light is required to bring eggs to maturity and fertilization. A shift from increasing to decreasing day length is associated with cessation of brood production. This feature of the relation of day length to brood production is shown in the left half of Fig. 1 which illustrates the effect in mature specimens. The effect is shown also in Fig. 3 which illustrates the relation between day length and cessation of brood production in young specimens which have been induced to produce young out of season. Clear cut results are obscured in the specimens shown in Fig. 2 because of overlapping conditions. Substituting a decreasing for an increasing day length in September, 1952 had the effect of delaying and extending the period of brood production. Changing from declining to increasing day length in December, 1952 would bring on brood production again the latter part of February. Apparently two conflicting sets of stimuli were produced by the changes in day length.

The effect of day length in relation to maturity in new born fish is shown in Fig. 3. A specimen born in March under continuous rising day length and room temperature has eggs ready for fertilization in about four months and will produce a brood in five months. This capacity for early maturity must be present in the new-born specimens in their natural habitat but low temperatures and a long period of declining day length may prevent an adequate secretion and utilization of a gonadotropic pituitary hormone.

A considerable degree of plasticity is demonstrated in the potentialities of the reproductive mechanism. Inherent capacities are adjusted to the conditions of varying temperature and day length as they occur in the natural environment. The species appears to have a considerable range of tolerance and would be able to survive new environmental conditions within the limits of the plasticity of its reproductive mechanism. The plasticity would enable the species, other factors being equal, to survive climatic changes within its present range.

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## SUMMARY

1. Specimens of *Jenynsia lineata* which breed in the spring and summer in Argentina become adapted easily to a permanent spring and summer breeding season in the northern hemisphere.

2. Specimens shifted from the southern to the northern hemisphere in September during their breeding season will finish a normal breeding cycle if they are kept on Argentina day length.

3. If the same specimens are shifted to northern hemisphere day length in March they will produce a second cluster of broods in May, June and July.

4. Young specimens born in the fall and early winter on normal northern hemisphere day length and continued on northern hemisphere day length mature early and produce broods in June, July and August.

5. Substitution of room temperature for the extremes of temperature in the natural habitat is partially responsible for early maturity of the fall and winter young but increasing day length is the principal controlling factor.

6. The beginning of brood production within two to three months can be induced in mature animals by substituting increasing for declining day length provided a previous period of declining day length is two months or more in length. Cessation of brood production is induced usually within two months by the substitution of declining for increasing day length.

7. Inherent reproductive features are: response to day length and temperature, brood size, interval in time between broods and number of broods per breeding season.

8. Experimentally induced departures from reproductive features occurring in the normal habitat indicate considerable capacity for plastic responses which could enable the species to survive climatic changes, other factors being equal.

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## A New Genus and Two New Species of Eastern Atlantic Clingfishes

JOHN C. BRIGGS

**D**URING the preparation of a monograph on the Xenopterygii, it was possible to locate only a few specimens from northwest Africa and none from the tropical waters of the West African coast south of Cape Verde. Recently, I was most gratified to receive a fine collection of clingfishes from this area through the kindness of Dr. J. Cadenat of the Institut Français d'Afrique Noire at Gorée in Sénégal. This collection included 10 specimens from three localities on the Gold Coast as well as a large number of individuals from the Dakar region. In this material were a distinct new genus and species and another new species, all described below. Thus it is possible to fill in an important gap in our knowledge of the evolution and distribution of this interesting group of fishes.

I am also indebted to Dr. L. Peigné of the Institut Océanographique at Monaco for sending an additional collection of specimens belonging to the genus *Lepadogaster*. This material

has helped to afford a much better conception of the distribution of the subspecies of *Lepadogaster lepadogaster*.

The description of each taxon follows the uniform plan and sequence adopted by the author (Briggs, 1955) for this order of fishes. The various counts and measurements were also taken in the manner described in this work.

### *Lecanogaster*, gen. nov.

Type species: *Lecanogaster chrysea*, sp. nov.

Body moderately depressed anteriorly; head elongated in dorsal outline, snout moderately produced and rounded at end. Head moderately depressed, length 2.2–2.4 and width 3.8–4.4 in standard length. Nostrils on each side well separated and distinctly tubular; anterior nostril

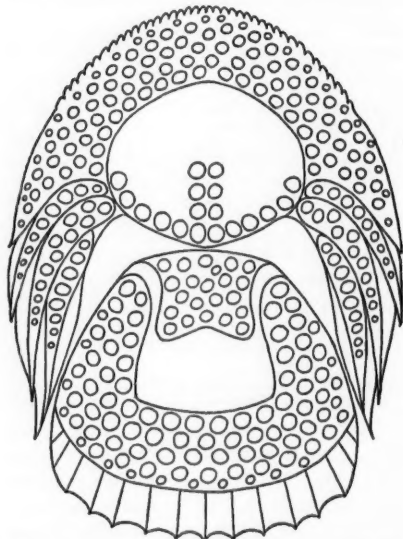


FIG. 1. Diagram of external appearance of disc from a ventral view, genus *Lecanogaster*. In life there may have been more papillae in the central anterior portion than are indicated here.

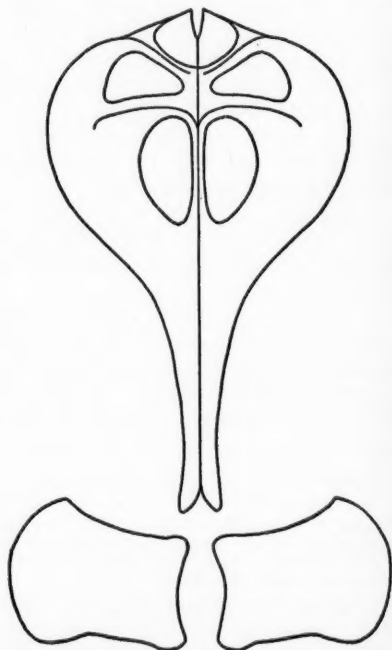


FIG. 2. Outline of bony disc supports from a ventral view, genus *Lecanogaster*. Pelvis above and two distal postcleithral bones below.



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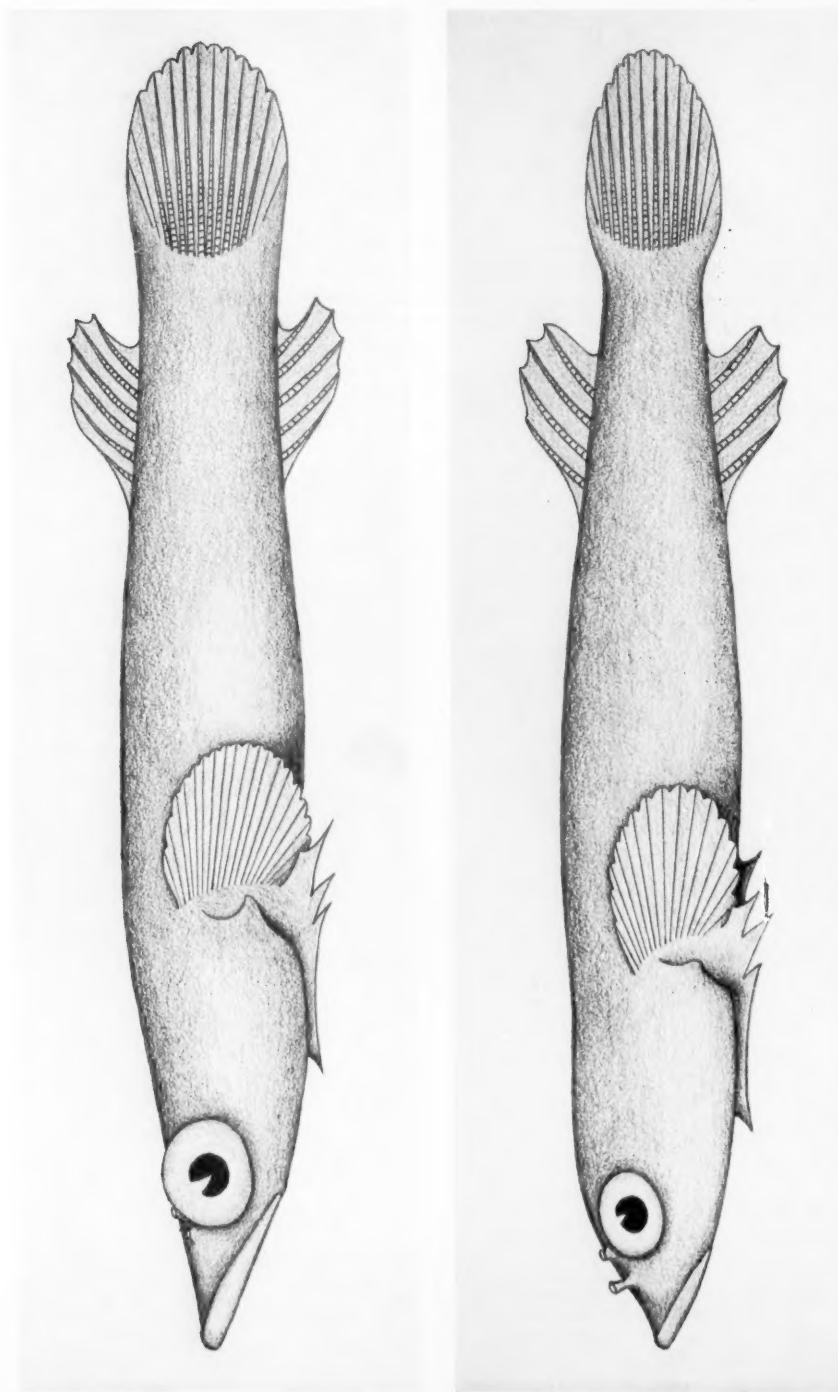


Plate I. Upper, *Lecanogaster chrysea* drawn from the holotype, 20.8 mm. in standard length. Lower, *Opedogenys cadenati* drawn from the holotype, 21.0 mm. in standard length.

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with an appendage on its posterior margin in the form of a very small dermal flap. Upper lip, as delineated by the premaxillary groove, narrow at tip of snout and comparatively wide at sides.

Teeth small, conical, recurved, in deep patches toward the front of each jaw, narrowing to a single row along sides of jaws, larger than those found at the front. Seven, shallow, blunt rakers on third gill arch. Edges of gill membranes attached laterally close to upper pectoral base and below the upper origin of this fin. A poorly developed fleshy pad on lower pectoral base.

Median fins short. Dorsal rays 5-6, anal rays 5, and caudal rays 10-12. Pectoral rays vary from 21-23. The dorsal and anal ray counts can be taken without much difficulty but the first pectoral ray is very small and apt to be overlooked. Disc medium in size, length 4.1-4.7 in standard length. The external structure of the disc is distinctive (Fig. 1) since there are papillae present in the center of the anterior portion, a condition not found in any of the other genera in this subfamily.

The premaxillary bones are elongated and spatulate, quite similar to those which have been figured (Briggs, 1955, Figs. 75 and 76) for the genus *Lepadogaster*. On the other hand, the shape and position of the maxillaries are about the same as has been illustrated (loc. cit., Fig. 74) for *Diplecogaster*. Subopercular element present; it is the terminal bone posteriorly on the head and bears no spine. The pelvis has a characteristic shape from a ventral view (Fig. 2) but the relationship to *Lepadogaster* is clearly apparent. There are 28 vertebrae.

There is no apparent external sexual dimorphism.

This genus is monotypic and, so far, is known only from the Gold Coast.

**DERIVATION OF NAME.**—The name is from the Greek *lekos*, plate, platter, dish, pan; and *gaster*, stomach or belly; in reference to the plate-like disc on the ventral surface of the animal.

In order that this new taxon may be readily recognized during routine identification work, a new key to the subfamily has been written which may be substituted for that which was presented earlier (Briggs, 1955: 22):

#### REVISED ARTIFICIAL KEY TO THE GENERA OF LEPADOGASTRINAE

- 1a. Dorsal and anal fins reduced to low ridges with the rays very weak; body long and narrow with 38 vertebrae; disc small, length 5.3-6.3 in standard length. .... *Gouania*.
- 1b. Dorsal and anal fins normal with strong rays; body comparatively short and broad with 28-34 vertebrae; disc larger, length 3.2-4.7 in standard length.
  - 2a. A strong, pungent, subopercular spine present ..... *Opeatogenys*
  - 2b. No spine in subopercular region.
    - 3a. Small incisors at the front of each jaw followed on each side by 1-3 canines; 6 rakers on third gill arch. .... *Apletodon*
    - 3b. No incisors or canines present; 7-18 rakers present on third gill arch.
      - 4a. Dorsal rays 13-21; anal rays 9-12 ..... *Lepadogaster*
      - 4b. Dorsal rays 4-9; anal rays 3-8.
        - 5a. Papillae present on central anterior region of disc (Fig. 1); a slightly developed fleshy pad on lower pectoral base; 28 vertebrae; shape of bony disc supports distinctive (Fig. 2) ..... *Lecanogaster*
        - 5b. No papillae on central anterior region of disc; no fleshy pad on lower pectoral base; 30-32 vertebrae; shape of bony disc supports distinctive (Briggs, 1955, Fig. 49) ..... *Diplecogaster*

#### *Lecanogaster chrysea*, sp. nov.

##### Plate I, upper

**DIAGNOSIS.**—A small fish with no subopercular spine and comparatively short dorsal and anal fins. There are papillae present in the central anterior portion of the disc and the entire structure is comparatively small. Dorsal rays 6 (5-6), anal rays 5, pectoral rays 22 (21-23), and caudal rays 11 (10-12).

**DESCRIPTION.**—Body medium in width and moderately depressed anteriorly, depth 5.9 (5.8-6.0) in standard length. Caudal peduncle short, depth 0.9 (0.8-0.9) in its length. Anus located closer to origin of anal fin than to rear margin of disc. Head moderately depressed, length 2.3 (2.2-2.4) and width 4.1 (3.8-4.4) in standard length. Snout in dorsal outline elongated and rounded, 3.1 (3.0-3.2) in head: A very small, narrow dermal flap on posterior margin of anterior nostril; posterior nostril located behind anterior edge of eye. Eye 0.7 in bony interorbital space and 4.0 (3.5-4.4) in head.

Upper attachment of gill membrane opposite 6th pectoral ray. Upper attachment of axial, dermal flap opposite 9th (9-10) pectoral ray. Postdorsal-caudal distance in dorsal length 0.6 (0.6-0.7); dorsal-caudal distance measured for-

ward extends to a point far behind the tip of the pectoral fin. Disc length 4.5 (4.1-4.7) in standard length; disc region A with 5 (4-5) rows of flattened papillae across its width; 4 rows across the width of region B; 5 rows across region C.

**COLORATION.**—In alcohol, no traces of pigmentation remain on the specimens. The life colors are unknown.

**RELATIONSHIP.**—So far there are no known close relatives of this, the only species in the genus.

**HOLOTYPE.**—Institut Français d'Afrique Noire 52.1210 (to be deposited in the British Museum); 20.8 mm. in standard length, collected by Dr. Bassindale at Ningo, Gold Coast, on December 10, 1950.

**PARATYPES.**—IFAN 52.1211 and 52.1212; two specimens 17.0 mm. and 17.5 mm. in standard length, taken with the holotype. The former has been cleared and stained.

**DERIVATION OF NAME.**—The name is from the Greek *chrysos*, gold; in reference to the Gold Coast, the type locality.

*Opeatogenys cadenati*, sp. nov.

Plate I, lower

**DIAGNOSIS.**—A small *Opeatogenys* with body only slightly depressed, depth 6.0 (5.7-6.2) in standard length. Seven short, blunt rakers present on third gill arch. Male with a long, slender, urogenital papilla, its length about one third body depth at anus. Dorsal rays 4 (3-5), anal rays 4 (3-5), pectoral rays 21 (20-22), and caudal rays 9 (8-10).

**DESCRIPTION.**—Caudal peduncle long, its depth 1.8 (1.6-2.1) in its length. Anus located closer to anal fin origin than to rear margin of disc, and well in front of dorsal origin. Head well depressed, length 2.8 (2.7-2.9) and width 4.0 (3.8-4.4) in standard length. Snout in dorsal outline short and rounded, 3.2 (3.0-3.7) in head. Posterior nostril above or behind anterior edge of eye. Eye 0.9 (0.8-1.1) in bony interorbital space and 3.9 (3.7-4.3) in head.

Upper attachment of gill membrane opposite 4th (4-5) pectoral ray. Upper attachment of axial, dermal flap opposite 10th (9-11) pectoral ray. Dorsal-caudal distance measured forward extends to a point behind the tip of the pectoral fin; postdorsal-caudal distance 0.4 (0.3-0.5) in dorsal length. Length of disc 4.2 (3.8-4.7)

in standard length; disc region A with 4 (3-4) flattened papillae across its width; 4 (4-5) papillae across the width of disc region B; 4 (3-4) papillae across region C.

**COLORATION.**—In alcohol, no traces of pigmentation remain on the specimens. The life colors are unknown.

**RELATIONSHIP.**—*O. cadenati* is easily separable from *O. gracilis*, the only other species in the genus. The former possesses more pectoral rays, a deeper body, and the upper attachment of the axial, dermal flap is lower. Also, there are seven rakers on the third gill arch compared to five in *O. gracilis*.

**HOLOTYPE.**—Institut Français d'Afrique Noire 51.1554; a male 21.0 mm. in standard length, collected by A. Blanc at Chenal de Joal, Sénégal, French West Africa, on May 19, 1951.

**PARATYPES.**—IFAN 52.1214-52.1216; three specimens 4.4 mm. to 9.9 mm. in standard length, collected at Prampram, Gold Coast, by Dr. R. Bassindale on February 13, 1949. IFAN 52.1213; one, 12.0 mm. in standard length, taken at Winneba, Gold Coast, by Dr. Bassindale on November 22, 1949. IFAN 52.1210-52.1212; three, 9.5 mm. to 18.9 mm. in standard length, taken at Ningo, Gold Coast, also by Dr. Bassindale on December 10, 1950. IFAN 51.519 and 51.520; two, 14.0 mm. and 20.0 mm. in standard length, collected at Devant Popenguine, Sénégal, by A. Blanc on May 19, 1951. IFAN 53.1978-53.1981; four, 8.4 mm. to 17.2 mm. in standard length, taken at Gorée, Sénégal, by Dr. J. Cadenat on June 23, 1953. IFAN 50.2388; one, 7.4 mm. in standard length, captured at Gorée, Sénégal, by M. Delais on June 13, 1950. IFAN 1786; one, 18.0 mm. (cleared and stained) in standard length, taken at Gorée, Sénégal, by Mlle. M. Sarre.

**DERIVATION OF NAME.**—This interesting new species is named for Dr. J. Cadenat, Chef de la Section Biologie Marine de l'Institut Français d'Afrique Noire, in recognition for his excellent work on the fishes of Sénégal and in gratitude for his kindness in sending me a fine collection of clingfishes from West Africa.

**REMARKS.**—At the time of its description (Briggs, 1955: 24), the genus *Opeatogenys* was thought to be monotypic and confined to the Mediterranean Sea. The discovery of *O. cadenati* makes it necessary to somewhat alter the original concept of this genus so that the variation

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between the two species may be taken into account. The following information may be substituted for that given in the original generic description: Head length 2.7–2.9 and width 3.8–4.4 in standard length. Five to seven short, blunt rakers on third gill arch. Dorsal rays 3–5, anal rays 3–5, caudal rays 8–10, and pectoral rays 16–22. Disc length 3.8–4.7 in standard length. There are 29–30 vertebrae and 5–6 branchiostegals.

When *Opeatogenys* was first described, only a single specimen (a male) was available for examination. However, it was predicted that an external sexual dimorphism probably existed. This has been borne out by the finding of a well marked dimorphism in *O. cadenati*. The males possess a comparatively large and elongate urogenital papilla (Fig. 3). Apparently this structure is even more highly developed in the Mediterranean species, *O. gracilis*, if the single specimen seen proves to be typical.

The range of the genus *Opeatogenys* may now be defined as extending from the Gold Coast to the Adriatic. Of the six genera now known in the Lepadogastrinae, only one (the monotypic *Gouania*) is confined to the Mediterranean Sea.

#### EVOLUTION AND DISTRIBUTION

The inclusion of the new genus, *Lecanogaster*, plus the one additional species of *Opeatogenys* make it necessary to consider the relationships of these two new entities and their place in the evolutionary and distributional history of the subfamily Lepadogastrinae.

Of the five previously recognized genera of Lepadogastrinae, *Lepadogaster* was considered

the most primitive and evidently gave rise to *Diplecogaster* and then *Apletodon* in a more or less straightforward sequence of evolutionary changes. The highly modified genera *Gouania* and *Opeatogenys* were considered to be long-separated offshoots of the *Lepadogaster*-*Diplecogaster*-*Apletodon* line.

*Lecanogaster* fits very nicely into the above scheme, occupying a position approximately midway along the scale of change from *Lepadogaster* to *Diplecogaster*. Although the pelvis of this new genus is considerably more elongate (Fig. 2), it is far closer to the *Lepadogaster* type than any other. Also the distal postcleithral bones, which lie posterior to the pelvis, are very similar to those of *Lepadogaster* in both shape and position. The same comment can be made regarding the shape of the premaxillaries. On the other hand, the configuration and location of the maxillaries are virtually the same as illustrated for *Diplecogaster* (Briggs, 1955, p. 190, Fig. 74).

*Lecanogaster* still retains a poorly developed fleshy pad on the lower pectoral base, a primitive feature also exhibited by *Lepadogaster* but not found in the other genera. However, both the dorsal and anal fins of the former are very short and have few rays (D. 5–6, A. 5) compared to those of *Lepadogaster* (D. 13–21, A. 9–12), but do fit into the range of variation in the four species of *Diplecogaster*. These, then, are the principal reasons for the placement of the new genus between *Lepadogaster* and *Diplecogaster* in evolutionary sequence.

Heretofore, all 12 species in the Lepadogastrinae had been known only from temperate waters, 11 from the northeastern Atlantic and one from deep water off Durban, South Africa. The tropical West African Region, extending according to Ekman (1953: 56) from, roughly, the southern part of Angola (15° S) to Cape Verde (15° N), was the only major warm water area of the world from which clingfishes had not been reported. Both new species described here occur within this region, with one (*Opeatogenys cadenati*) extending to its northern boundary. These records, beside filling a zoogeographic gap, give further evidence of endemism among the shore fishes of this area. The subfamily Lepadogastrinae now consists of six genera and 14 species which, with one exception, are confined to the temperate and tropical waters of

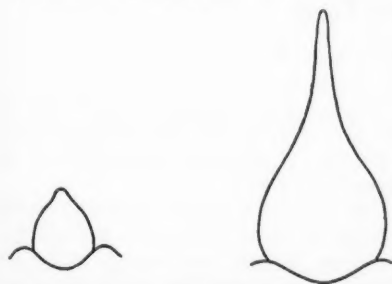


Fig. 3. Outline of urogenital papillae from a ventral view, *Opeatogenys cadenati*. Male right; female left.

the Eastern Atlantic. The exception, as mentioned above, is *Diplecogaster megalops* from off southeast Africa.

#### THE SUBSPECIES OF *LEPADOGASTER* *LEPADOGASTER*

*Lepadogaster lepadogaster* is the most common Eastern Atlantic clingfish and is, perhaps, the best known of any species in the entire family. When the question of its two subspecies was first dealt with (Briggs, 1955: 35) it seemed probable that *L. l. lepadogaster* was a southern form extending from Dakar throughout the Mediterranean and *L. l. purpurea* a northern form ranging from Roscoff, on the Atlantic coast of France, to the Shetland Islands. Although a comparatively large number of specimens (88) were examined at that time, only four of them came from the West African area (one from Cape Verde, two from the Canaries, and one from the Salvage Islands).

The loan of clingfish material from Dr. Cadenat contained 144 individuals from the Dakar vicinity and shows conclusively that the subspecies from that area is *L. l. purpurea* and not *L. l. lepadogaster*. Therefore, it is quite apparent that these two infraspecific forms are divided geographically in eastern and western rather than northern and southern groups. Although the two specimens from the Canaries and the one from the Salvage Islands were previously identified as *L. l. lepadogaster*, they were

in rather poor condition and might actually belong to the other subspecies. For the present, however, *L. l. lepadogaster* should be considered a Mediterranean subspecies which extends out in the Atlantic to include these offshore localities. This leaves *L. l. purpurea* as the mainland form occurring outside the Mediterranean from Dakar north to the Shetland Islands.

The material recently sent from the Institut Océanographique at Monaco by Dr. L. Peigné has helped to shed light on the area in which the separation between the eastern and western subspecies takes place. Three apparently typical *L. l. lepadogaster* were taken in the vicinity of Monaco but four specimens comprising a single collection from Cap Roux, a locality on the French Mediterranean coast only a short distance (about 210 klm.) west of Monaco, were identified as *L. l. purpurea*. Therefore, the separation must take place between the above two points and not at the entrance to the Mediterranean. A similar dividing point may exist on the Mediterranean coast of North Africa.

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## Structure of the Call and Relationships of *Bufo microscaphus* Cope

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THE relationships of the toad described by Cope (1867) as *Bufo microscaphus* have been variously misinterpreted until very recent time. Shannon (1949) contributed toward clarification of these relationships when he regarded *microscaphus* as a subspecies of *B. woodhousei*. Stebbins (1951) treated *microscaphus* as a distinct species which hybridizes in nature with *woodhousei*. A. P. Blair (1955) after an extensive study of geographic variation

in morphologic characters agreed generally with Stebbins and theorized that *microscaphus* is a disjunct, allopatric representative of the *americanus* group.

The present work was undertaken so that characteristics of the mating call could be analyzed for additional evidence of the relationships of *microscaphus* to *americanus* and *woodhousei*. Five days from June 14 to 18, 1955, were spent in Washington County, Utah,



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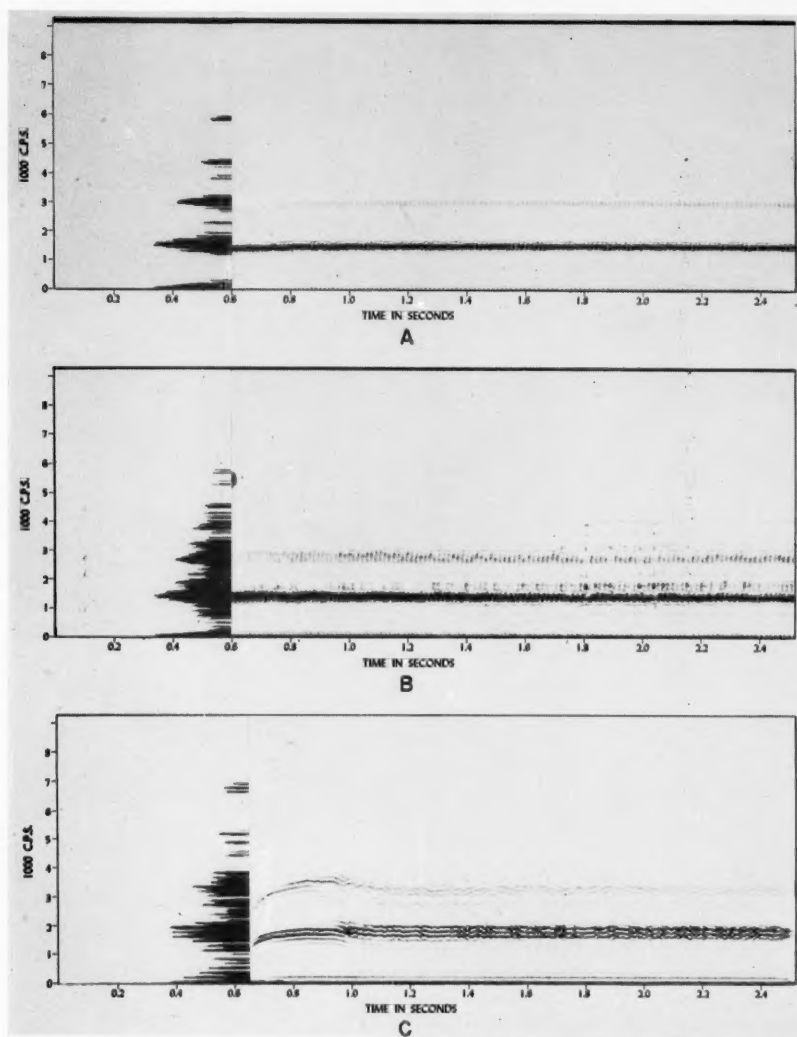


Plate I. Sonograms (right) and "sections" (left) of toad calls from Washington County, Utah. Sonograms show time on horizontal axis, versus frequency (to 8 kc per second) on vertical axis, versus intensity (darkness of marking). Sections show amplitude (length of horizontal lines) versus frequency (vertical axis). (A) *Bufo microscaphus* from Baker Reservoir, (B) *microscaphus*-like possible recombination type from Lower Sand Cove Reservoir, (C) *B. woodhousei* from Virgin River near St. George.

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making tape recordings of toad calls. These calls have been analyzed on a sound spectrograph (Sona-Graph).

This work was done under National Science Foundation Projects No. G-328 and G-2215.

#### MATERIALS

Tape recordings were made at three stations, which represent a transect from the Virgin River at St. George up Santa Clara Creek. These stations are as follows:

**VIRGIN RIVER.**—Recordings were made of eight individuals in a moderate chorus of toads which were calling in a tule (*Typha*) marsh about two miles south-southeast of St. George, on the floodplain of the Virgin River. The calling toads were scattered widely through the tule marsh. All toads in a sample of six collected showed the morphological features of *B. woodhousei*. All had an interorbital plateau, a distinct dorsal stripe, and the general color pattern of *woodhousei*. The ratio of parotoid width to length (L/W) ranged from 1.85 to 2.32 and averaged 1.96.

No toad calls other than the short, snoring calls of the kind recorded were heard in this aggregation. Analysis of the eight calls (Table 1) showed them to vary in length from 1.0 to 2.1 seconds and to average 1.7. The dominant frequency ranged from 1750 to 1950 cps and averaged 1857. The calls of these toads were untrilled, and the sound spectrograph revealed the same side band structure (Pl. I, C) that is characteristic of other geographic subpopulations of *woodhousei* (W. F. Blair, 1956).

**BAKER RESERVOIR.**—The calls of two individuals were recorded. These were the only two toads calling along a section of rocky, wooded stream below Baker Reservoir Dam, which is about two miles south of the town of Central. Both toads were sitting on the bottom and calling from shallow water in the edge of the stream. Both toads fitted *B. microscaphus* in morphological characters. One lacked supra-orbital crests and the other had faint crests. The dorsal stripe was faint in one and lacking in the other. The ratio of parotoid width to length (L/W) was 1.49 in one and 1.55 in the other. A. P. Blair (1955) obtained a large series of *microscaphus*, but no *woodhousei* or presumed hybrids, at Baker Reservoir.

The call of one of these toads had an average

duration of 3.3 seconds, and that of the other was 3.4 seconds (Table 1). The dominant frequency was 1350 cps in the first and 1250 in the second. The repetition rate in the call of the first toad averaged 49 trills per second in the first half of the call and slowed to 45 trills per second in the last half. The trill rate averaged 49 trills per second in the first half and 44 in the second in the calls of the second toad. The structure of the call of the first toad showed no side band effects (Pl. I, A), while that of the second showed moderate side band structure.

**LOWER SAND COVE RESERVOIR.**—The calls of seven individuals were recorded in a moderate chorus of toads at this station, which is located south-southwest of Veyo. Most of the toads were calling along about 50 feet of shoreline on a sandy shallow side of the reservoir. The toads were sitting on the bottom, and there was a great deal of moving about of individuals. A large chorus of *B. punctatus* was in progress in deep water on the opposite side of the reservoir, where the toads were concentrated on floating vegetation. One *microscaphus* call was heard in the edge of this *punctatus* chorus.

Five of the six toads collected had faint supra-orbital crests, and the sixth had well-developed crests. Five had a faint dorsal stripe, and the sixth had a prominent stripe. The parotoid length-width ratio (L/W) varied from 1.52 to 2.04 and averaged 1.69. All six had the general color pattern of *microscaphus*. The extremes of morphological characters (well-developed crests, prominent dorsal stripe, large parotoid L/W ratio) in which there was variation in the direction of *woodhousei* were found in different individuals.

The calls of the seven individuals recorded varied in length from 3.6 to 5.7 seconds and averaged 5.0 (Table 1). The dominant frequency ranged from 1100 to 1550 cps and averaged 1407. The repetition rate ranged from 54 to 66 and averaged 60 trills per second in the first half of the call and ranged from 47 to 65 and averaged 55 in the second half. Three individuals showed slight to no side band structure, while four showed distinct side banding.

#### RELATION TO *americanus*

The characters of the call of *B. microscaphus* strongly support the hypothesis advanced by

TABLE I

CHARACTERISTICS OF THE MATING CALL OF 17 INDIVIDUAL TOADS (*Bufo*) FROM WASHINGTON COUNTY, UTAH. DURATION, TRILL RATE AND STRUCTURE DETERMINED FROM SONAGRAMS (NARROW-BAND ANALYSIS). FREQUENCIES DETERMINED FROM SECTIONS

Samples	Temp °C		Duration in seconds	Frequency in CPS	Trills per second		Side band structure
	H <sub>2</sub> O	Air			In first half	In second half	
Baker Reservoir ( <i>microscaphus</i> )	16.0	14.0	3.3	1350	49	45	None
			3.4	1250	49	44	Yes
Virgin River ( <i>woodhousei</i> )	23.0	17.0	1.8	1750	—	—	Yes
			1.8	1800	—	—	Yes
			1.6	1825	—	—	Yes
			1.0	—	—	—	Yes
			2.0	1850	—	—	Yes
			1.9	1925	—	—	Yes
			1.7	1950	—	—	Yes
			2.1	1900	—	—	Yes
Lower Sand Cove Reservoir ( <i>microscaphus</i> -like)	17.0	17.0	5.1	1500	65	59	None to slight
			4.6	1400	57	56	Moderate
			4.9	1100	54	47	Moderate
			5.6	1550	66	65	Yes
			5.7	1400	61	54	Yes
			5.4	1400	60	52	None to slight
			3.6	1500	57	55	None to slight

A. P. Blair (1955) on morphological grounds that this toad belongs with the *americanus* group, which includes *americanus* and the allopatric species *terrestris* and *houstonensis* of the eastern United States.

The call of *microscaphus* is closely similar in several respects to that of the eastern representatives of the *americanus* group. One of the two individuals from Baker Reservoir and three of the seven from Lower Sand Cove Reservoir show the same kind of fine tuning, without side-band structure, (Pl. I) that is characteristic of the eastern species of the group (W. F. Blair, 1956a). The call in these four individuals (Table 1) ranges from 3.3 to 5.4 seconds in length, which is shorter than in *americanus* but within the range of variation of *terrestris*. The only other toad of the southwest which resembles *americanus* in frequency structure of the call is *punctatus*, which is sympatric with *microscaphus*, but, which on morphological characters does not appear to be closely related to it.

The call of *microscaphus* differs from that of local *woodhousei* in the same way that the call of *americanus*, *terrestris* or *houstonensis* differs

from that of sympatric representatives of the *woodhousei* group. The call of the *americanus*-group representative is relatively long, musical and trilled, while that of the *woodhousei*-group representative is relatively short, unmusical and untrilled.

#### RELATION TO *woodhousei*

The evidence from previous workers that *woodhousei* and *microscaphus* populations interbreed in southwestern Utah is supported by the analyses of call structure. All of the toads recorded and collected at our station on the Virgin River appear to be good *woodhousei* on morphology and on call structure. A. P. Blair (1955) recorded both species and hybrids from this same area, but only *woodhousei* was calling there at the time of our visit.

Our toads from Lower Sand Cove Reservoir show some suggestion of *woodhousei* characters in that one has well-developed crests, one has a good dorsal stripe, and one has a high parotoid length/width ratio. On the sum of their morphological characters all of these toads are, however, much closer to *microscaphus* than to *woodhousei*. In call, three of the toads recorded

show essentially no side-band structure, while four show conspicuous side-band effects (Pl. I, B). Both frequency and repetition (trill) rate are higher in these toads than in those recorded at Baker Reservoir, although this may result in part from the slightly higher air and water temperatures at which the Sand Cove Reservoir recordings were made. Acceleration of the trill rate is, however, characteristic of hybrids between trilling species of toads and *woodhousei* (W. F. Blair, 1956b). The duration of the call is unexplainably longer than in Baker Reservoir *microscaphus* and much longer than in the Virgin River *woodhousei*. Their side-band structure, higher frequency and higher repetition rate than in Baker Reservoir *microscaphus* suggest that four of the seven toads recorded at Lower Sand Cove Reservoir may represent recombinations from the back-crossing of past *woodhousei-microscaphus* hybrids to *microscaphus*. A. P. Blair (1955) reported *microscaphus* and "hybrids," but no *woodhousei*, from a nearby reservoir (Upper Sand Cove).

One of the two *microscaphus* recorded at Baker Reservoir shows side band structure suggestive of past introgression of genes into that population, but in other characters of the call it does not differ markedly from the other toad recorded there.

Lower Sand Cove Reservoir is some 18 miles from the Virgin River airline and about 30 miles by way of Santa Clara Creek. Baker Reservoir is about 22 miles airline from the river and about 40 miles by way of Santa Clara Creek. There does appear, therefore, to be some introgression of *woodhousei* characters up the tributary streams. Evidence for this is also found in the "hybrids" reported by A. P. Blair (1955) from Upper Sand Cove Reservoir.

The cross breeding of *microscaphus* and *woodhousei* is simply another case of interbreeding of representatives of the *americanus* and *woodhousei* groups where members of these groups occur sympatrically. It is of interest that all well documented cases of natural hybridization between species of North American toads involve the *woodhousei* group. These include: *valliceps-woodhousei* (Thornton, 1955); *fowleri-americanus* and *fowleri-terrestris* (A. P. Blair, 1941), and *woodhousei-microscaphus*. In addition, I have in my laboratory a toad collected by John Wottring of Houston which I suspect to be a hybrid between *fowleri* and *houstonensis*.

Shannon (1953) has reiterated his opinion that *microscaphus* is a subspecies of *woodhousei*. There seems no question but that *woodhousei* and *microscaphus* are interbreeding to some extent in southwestern Utah. However, there also seems to be no question but that this is secondary interbreeding as the result of a reticulate evolutionary path in the *woodhousei-americanus* complex. Ancestral *americanus* and *woodhousei* embarked on separate evolutionary lines. Ancestral *americanus* differentiated into allopatric species which have retained their disjunct distributional relationships. Ancestral *woodhousei* split into the allopatric *woodhousei* and *fowleri* which later established secondary breeding contact. Finally, gene exchange was reestablished between the allopatric species of the *americanus* group and sympatric representatives of the *woodhousei* group. This complex evolutionary history seems best portrayed by treating each of the allopatric species of the *americanus* group as a separate species which does hybridize to some extent with local representatives of the *woodhousei* group. The precise amount of hybridization and the specific effects on the isolation mechanism complexes of the hybridizing species remain to be determined for all of the combinations of *woodhousei* and *americanus*-group representatives, and it is not until these are determined that a precise evaluation of the evolutionary position of these populations can be made.

#### SUMMARY

Analyses of the calls of *Bufo woodhousei* and *B. microscaphus* from southwestern Utah were made by use of a sound spectrograph. The call of *B. microscaphus* shows similarities to the calls of eastern species of the *americanus* group of toads. This is additional evidence that the relationships of *microscaphus* lie with this group of toads, although it is at present widely disjunct from other representatives of the group. Some introgression of *woodhousei* genes up tributaries of the Virgin River is suggested by the character of the call in populations at reservoirs along Santa Clara Creek. Although hybridization with *woodhousei* does occur, *microscaphus* seems best regarded as a distinct species rather than as a subspecies of *woodhousei*.

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An Altitudinal and Latitudinal Cline in *Rana pipiens*

RODOLFO RUIBAL

ONE of the most debated herpetofaunal problems in North America concerns the variation and subspeciation of the Leopard Frog, *Rana pipiens*. This species is a unique member of the North American vertebrate poikilothermous fauna in having a range that extends from the Great Slave Lakes in Northern Canada to Panama. Concomitant with this range is the great morphological variation exhibited by the different geographical populations of this species. Numerous morphological studies have been made of the variation of this species. The most thorough and recent (Moore, 1944), consisted of an analysis of a number of morphological characters of frogs from the eastern portion of the United States. Moore concluded that the variations exhibited by the different eastern populations were so irregular as to make the recognition of subspecies impractical. Other herpetologists have been unwilling to follow Moore's conclusions. Thus Wright and Wright (1949) consider the United States populations of *R. pipiens* to be divisible into three species, with one of the species having 6 subspecies. With the exception of *Rana pipiens pipiens* and *Rana pipiens sphenocphla* Wright and Wright fail to present convincing evidence for recognizing the different forms. More recently, Schmidt (1953), essentially followed Wright and Wright though he reduced the system to a single species with 5 subspecies.

The Mexican populations of *R. pipiens* have been split by Smith (1947) into two subspecies. Smith, however, provided a very inadequate diagnosis of the subspecies. Shannon (1951) attempted to give the Mexican subspecies a sounder morphological description but with little success. All the attempts to describe subspecies of *R. pipiens* have been characterized by a lack of information and comprehension of the variations exhibited by the species over its entire range.

In the present work the variations of a single morphological character have been analyzed. The data are from populations of *R. pipiens* from Canada, the United States and Mexico. These data are not presented with the intention of establishing subspecies on the basis of this single character. Rather the purpose is to present evidence for a well marked clinal character in *R. pipiens* correlated with altitude and latitude. It is hoped that by analyzing this single character, the groundwork can be provided for an interpretation of the variations. A similar study of three or four more characters might provide sufficient information to permit the defining of subspecies, assuming of course, that it would prove desirable or meaningful, to recognize subspecies.

*The character.* The character studied, namely, the shape of the snout, has been observed and noted (Kaufeld, 1937) by many students of



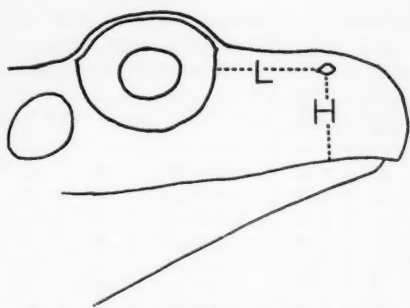


Fig. 1. Diagrammatic drawing of a lateral view of a frog head to demonstrate the measurements of the H/L ratio.

*R. pipiens*. Prior work has been unsatisfactory since the snout was described in purely subjective terms such as "pointed," "blunt," etc. In the present work it was possible to express this snout shape, in a quantitative manner, as a ratio of two separate measurements.

The ratio used is termed the H/L ratio. The measurement of L, length, is made from the anterior margin of the orbit to the external naris (Fig. 1), while H, height, is the distance from the external naris to the edge of the upper lip. The frogs with short blunt snouts are characterized by a high H/L value (1.15 or above) while the long snouted frogs have low values (around 1.00). The measurements of adult frogs were made with a Vernier calipers. When measuring L with calipers the anterior border of the eye is actually the posterior margin of the nasal bone. One edge of the calipers is inserted into the orbit and braced against the nasal bone. Recently metamorphosed individuals were measured using a dissecting microscope and an ocular micrometer. As a consequence of this difference in method of measuring, the H/L values of recently metamorphosed and adult frogs are comparable, but not identical.

#### MATERIAL

All of the frogs measured for the H/L ratio were preserved specimens from the collections of the American Museum of Natural History, the Museum of Comparative Zoology, the University of Michigan Museum of Zoology, the University of California Museum of Vertebrate Zoology, and the author's own collection.

Only those series of 10 or more specimens are reported so as to facilitate comparisons between localities.

The localities of the different samples are tabulated in Table I and Table II, together with the H/L value. In most instances the samples are series from a single locality or from two localities within the same county or adjacent counties. These localities are listed by merely giving the state and county or other appropriate geographic designation. Those samples (Maine, Massachusetts, Idaho, Wyoming) that are actually the result of lumping a number of specimens from different localities within a state are listed by merely giving the state. All of the Mexican series are samples from a single locality, with the exception of the Tamaulipas material which represents frogs from three localities in the lowlands of the Rio Soto la Marina drainage system.

Unfortunately the present work suffer from a lack of sufficient samples from the mid-western and southeastern United States. Small (less than 10 specimens) samples from these areas have been studied and in all instances support the present interpretations.

#### RESULTS

*H/L of Rana pipiens*.—The H/L values are tabulated for the United States and Canadian localities in Table I, and for Mexican localities in Table II. For the United States and Canada it can be readily seen that the value of H/L varies directly with the latitude (Fig. 2). Thus the northernmost localities of Canada, Maine, Massachusetts, Vermont, Colorado, Wisconsin, Idaho, Montana, Wyoming, Utah and Nevada, all between 40°–46° N latitude are characterized by H/L values between 1.13 and 1.30. The middle latitude (36°–41° N) localities of Long Island, New Jersey, North Carolina, Indiana, and Arkansas have H/L values between 1.00 and 1.11. The southernmost (26°–31° N Lat.) localities of Louisiana, Florida, and Texas have H/L values between 0.92 and 1.03. This tendency is most clearly evident along the east coast of the United States where the H/L value in Maine is 1.20, Massachusetts 1.20, Long Island 1.11, New Jersey 1.05, North Carolina 1.00, and the six Florida localities 0.92–0.99.

TABLE I  
H/L VALUES OF DIFFERENT POPULATION OF *Rana pipiens* FROM CANADA AND THE UNITED STATES

Locality	Latitude N	Number of specimens	Mean value of H/L	Range	$\sigma$	$\sigma_m$
Canada, Montreal	46	10	1.21	1.12-1.26	.07	.02
Montana, Pondera Co.	47	18	1.19	1.07-1.30	.07	.02
Maine	45	25	1.20	1.02-1.44	.12	.02
Vermont, Grand Isle Co.	45	22	1.28	1.16-1.39	.07	.02
Idaho	44	10	1.24	1.06-1.43	.11	.04
Wyoming	43	12	1.22	1.05-1.33	.08	.02
Massachusetts	42	17	1.20	1.06-1.36	.10	.02
Colorado, Boulder Co.	40	13	1.25	1.07-1.38	.11	.03
Utah, Salt Lake Co.	41	10	1.13	1.00-1.27	.10	.03
Nevada, White Pine Co.	40	12	1.23	1.08-1.42	.10	.03
Nevada, Clark Co.	36	23	1.26	1.13-1.58	.10	.02
Wisconsin, Winnebago Co.	44	20	1.30	1.22-1.48	.09	.02
New York, Long Island	41	13	1.11	1.00-1.21	.07	.02
New Jersey, Ocean Co.	40	12	1.05	.96-1.08	.04	.01
North Carolina, Coastal Plain	35	14	1.00	.82-1.18	.10	.03
Arkansas, Lawrence Co.	36	19	1.06	.88-1.30	.11	.03
Indiana, Monroe Co.	39	18	1.02	.89-1.10	.05	.01
Louisiana, Terrebonne Co.	29	13	.98	.92-1.07	.05	.01
Florida, Alachua Co.	30	15	.93	.84-1.02	.05	.01
Florida, Pinellas Co.	28	23	.95	.85-1.04	.05	.01
Florida, Marion Co.	29	10	.94	.88-1.02	.04	.01
Florida, Dade Co.	26	22	.99	.87-1.17	.08	.02
Florida, Duval Co.	30	10	.96	.88-1.02	.05	.02
Florida, Palm Beach Co.	27	18	.92	.86-1.06	.07	.02
Texas, Ward Co.	31	18	.99	.88-1.09	.06	.02
Texas, Webb Co.	27	15	1.03	.92-1.14	.06	.02
Arizona, Huachuca Mts.	31	30	1.33	1.13-1.59	.14	.03
Arizona, Chiricahua Mts.	32	10	1.47	1.36-1.55	.05	.02
California, Imperial Co.	33	25	1.21	1.04-1.40	.10	.02

TABLE II  
H/L VALUES OF DIFFERENT POPULATIONS OF *Rana pipiens* FROM MEXICO

Locality	Altitude in meters	Number of specimens	Mean value of H/L	Range	$\sigma$	$\sigma_m$
Coahuila, Las Delicias	1,000	14	1.06	.90-1.25	.10	.03
Chihuahua, Santa Barbara	1,900	10	1.28	1.18-1.50	.10	.03
Sonora, Nogales	1,110	13	1.20	1.05-1.31	.08	.02
Tamaulipas, Rio Soto la Marina	100	22	.97	.87-1.12	.05	.01
San Luis Potosi, Valles	70	10	.91	.86-.95	.03	.01
San Luis Potosi, Axtla	200	19	1.01	.89-1.13	.07	.02
Puebla, San Diego	350	25	1.00	.84-1.07	.07	.01
Puebla, Villa Juarez	1,200	10	1.07	.99-1.20	.06	.02
Hidalgo, Rio Tula	1,600	25	1.21	.98-1.49	.11	.02
Hidalgo, Velasco	2,200	13	1.25	1.03-1.46	.13	.04
Hidalgo, El Chico	2,900	25	1.42	1.21-1.66	.10	.02
Morelos, Zempoala	3,000	25	1.36	1.22-1.53	.08	.02
Chihuahua, El Vergel	2,400	11	1.44	1.23-1.68	.13	.04

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In Mexico a cline is evident but it is correlated with altitude. The localities below 1,000 meters have H/L values between 0.91 and 1.01. The populations from between 1,000 meters and 2,000 meters have values from 1.06 to

1.28. The populations above 2,000 meters vary from 1.25 to 1.44.

*H/L value of other species.*—As has been pointed out by Huxley (1943) related species usually demonstrate clines in the same charac-



Fig. 2. Outline map showing the distribution of the mean H/L values of the populations studied. The dotted line denotes the presumed boundary of the two groups of *R. pipiens* discussed in the text.

TABLE III  
H/L VALUES OF DIFFERENT SPECIES OF THE GENUS *Rana*

Species	Locality	Number of specimens	Mean H/L	Range	$\sigma$	$\sigma_m$
<i>R. clamitans</i>	New York	10	1.25	1.19-1.34	.05	.02
	Florida	10	1.03	.96-1.12	.06	.02
<i>R. sylvatica</i>	Northern Canada	14	1.30	1.07-1.50	.12	.03
	Long Island, New York	15	1.11	1.00-1.22	.07	.02
<i>R. palustris</i>	New York	13	1.18	1.07-1.30	.07	.02
<i>R. virgatipes</i>	New Jersey	10	1.18	1.06-1.34	.09	.03
<i>R. grylio</i>	Florida	12	.99	.88-1.10	.01	.00
<i>R. capito</i>	Florida	13	.91	.85-.98	.05	.01

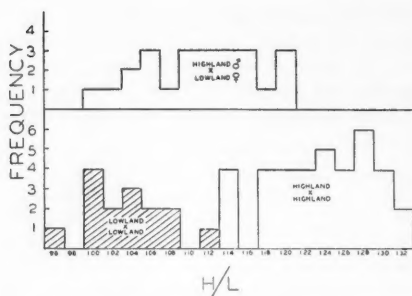


Fig. 3. Histogram of the H/L values of recently metamorphosed frogs raised in the laboratory under uniform conditions.

ters. This holds true in the case of the H/L value. Table III presents the data on six other species of the genus *Rana*. In *R. clamitans* and in *R. sylvatica* two different populations of each species were tested and it can be seen that within each species the more northern population has the higher H/L value. Similarly if we compare some northern species (*R. palustris* from New York and *R. virgatipes* from New Jersey) with southern species (*R. gryllio* and *R. capito* from Florida) the same relationship appears to exist.

**Genetic test of H/L ratio.**—The possibility that the H/L ratio was an environmentally induced character without any genetic basis was considered. This was tested in two ways. First, tadpoles from populations of different H/L ratios were raised to metamorphosis under identical laboratory conditions to see if the juveniles showed differences similar to that of the parent populations. In addition crosses were made between individuals from populations of different H/L values and the H/L of the  $F_1$  was measured.

The populations chosen were highland Mexico (Zempoala and El Chico) and lowland Mexico (San Diego). The adults of the highland populations have a mean H/L value of

1.36 or 1.42 and of the lowlands populations a mean H/L value of 1.00 (see Table II). The following crosses were made: highland  $\times$  highland, lowland  $\times$  lowland, and lowland  $\times$  highland. These crosses and the localities are described in more detail in Ruibal (1955).

All the tadpoles were raised under essentially uniform conditions. The eggs used in these experiments were all fertilized within a 24 hour period. The tadpoles were kept in the laboratory in large flat glass pans. They were fed a diet of egg yolk, spinach, and pablum. The temperature of the water in the pans fluctuated, from 18° C to 25° C., and the mean temperature was 22.6° C. The tadpoles were allowed to metamorphose and develop until the tail bud was reabsorbed. They were then fixed in 10% formalin and later transferred to 70% alcohol.

If the H/L ratio was an environmentally induced character we would expect all the young metamorphosed frogs to be characterized by the same H/L value. In contrast if the ratio has a genetic basis, we would expect the highland  $\times$  highland and lowland  $\times$  lowland frogs to reflect the differences of their respective populations, while the hybrids between the two would be intermediate in the H/L value (this is assuming that the H/L value is a polygenic character).

The results obtained are tabulated in Table IV, and represented in histogram form in Figure 3. The values of H/L obtained clearly demonstrate that in these Mexican populations the value has a genetic basis.

#### DISCUSSION

It is obvious from the data that the correlation of a high H/L value with the more northern latitudes is well demonstrated for the eastern half of the United States. In the case of the western states it is evident that this correlation does not hold (see map, fig. 2). Thus the

TABLE IV  
H/L VALUES OF YOUNG METAMORPHOSED FROGS RAISED IN THE LABORATORY

Cross	Number of specimens	Mean H/L value	Range	$\sigma$	$\sigma_m$
Highland $\varnothing \times$ Highland $\sigma$ .....	37	1.23	1.14-1.33	.05	.01
Lowland $\varnothing \times$ Highland $\sigma$ .....	24	1.12	1.00-1.21	.06	.01
Lowland $\varnothing \times$ Lowland $\sigma$ .....	15	1.04	.96-1.13	.04	.01

H/L value for Montana ( $47^{\circ}$  N. Lat.) is 1.19, while the Huachuca Mts. population in Arizona ( $31^{\circ}$  N. Lat.) has a mean H/L value of 1.30. This is actually a reversal of what would have been expected. A glance at the data for the Mexican localities immediately explains this anomalous relationship. In the case of all the Mexican populations a high H/L value is correlated with high altitude. Consequently the two Arizona localities if considered as part of the Mexican data are no longer anomalous. Both the Huachuca Mts. and Chiricahua Mts. specimens were probably collected at or above 1,650 meters (5,400 feet), and their H/L values are comparable to those obtained for the Mexican localities above 2,000 meters.

Another population having an H/L value that does not correlate with its latitude is that from Imperial Co., California. Here we have a population at approximately  $33^{\circ}$  N. Lat. having a mean H/L value of 1.21; a value comparable to that of populations from Montana and New England. The exact locality of this population of *R. pipiens* is San Felipe Creek, on the west side of the Salton Sea, at an elevation of 125 feet below sea level. It is possible that this population was introduced from the lower Colorado River; it would still not correlate with latitude. The H/L value of this population obviously neither fits the latitudinal cline of the United States populations nor the altitudinal cline of the Mexican populations.

As a working hypothesis it may be assumed that the altitudinal and latitudinal clines of the species are paralleled by some environmental gradient. This environmental gradient would provide a selective force that would operate to allow the evolution of the various H/L values. This implies that the same environmental factor is operating to create the latitudinal as well as the altitudinal cline. Consequently it immediately suggests that temperature, the only environmental factor that varies similarly with altitude and latitude, would show some correlation with the H/L values. In line with this reasoning various measures (extreme minimum temperature, mean temperature of the warmest month, etc.) of the environmental temperature of the different localities were plotted against the H/L values. In most instances there was no correlation between the H/L value and the

temperature statistic. However, when the mean H/L values were plotted against the mean temperature of the coldest month a correlation was found. As is shown in Figure 4 the populations fall into two distinct groups that demonstrate an increase of the H/L value with a decrease in the mean temperature of the coldest month. One group consists of the Mexican populations, as well as the populations from southern Texas, southern Arizona, southern California, and southern Nevada. The other group consists of the remaining United States and Canadian populations. This geographical separation is shown in Figure 2 by the dotted line. The two groups seem to merge, or overlap, in the case of the southern Florida localities and the tropical Mexican localities (upper left hand corner of Fig. 4). Since both groups show a correlation of the H/L value with the mean temperature of the coldest month, the only difference between the two is that when populations from localities having the same mean temperature of the coldest month are compared, the Mexican or southwestern populations will have a higher H/L value than the corresponding popu-

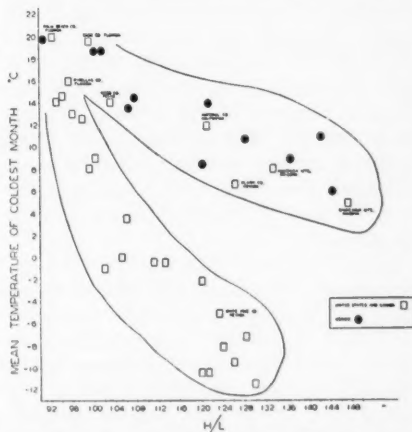


Fig. 4. The mean H/L values plotted against the mean temperature of the coldest month. The temperature data were obtained from Baker (1936), Bravo and Ramirez (1951), Contreras (1942), United States Department of Agriculture (1941), and the United States Department of Commerce (1930). Wherever data was not available for the exact locality listed, the nearest or most equivalent locality for which data was available was chosen. All the localities listed on Tables I and II are plotted, with the exception of Wyoming, Idaho, Tamaulipas, and Velasco, Hidalgo.

TABLE V  
COMPARISON OF THE MORPHOLOGY OF THE TWO  
POPULATIONS OF *Rana pipiens* FROM NEVADA  
REPORTED ON IN THE TEXT

Clark Co. (southern Nevada)	White Pine Co. (northern Nevada)
1. Mean H/L value = 1.26	1. Mean H/L value = 1.23
2. Males without vestigial oviducts. (3 specimens)	2. Males with vestigial oviducts. (16 specimens with oviducts and one specimen without oviducts)
3. Yellow on ventral surface of legs and venter.	3. No yellow on ventral surfaces.
4. Pigmentation of the posterior surface of the femoral region forming a diffuse reticulum.	4. Pigmentation of the posterior surface of the femoral region forming isolated dark spots.

lation from the other group. The Mexican and southwestern populations have mean H/L values that range from .91 to 1.47 while the other United States populations have values that range from .92 to 1.30. We may refer to the cline as a temperature related cline, its altitudinal and latitudinal association being the reflection of its temperature dependency.

With this in mind, it is obvious that the Imperial Co., California population is no longer anomalous. The latitude or altitude of this locality is merely not a good measure of the local climatic conditions. This locality is in the Colorado Desert, in a region of very high summer temperatures and of winter temperatures that fall below freezing for only a few nights of the year. The mean H/L value of the California population is 1.21, essentially the same as that of the Rio Tula and Nogales populations.

It is of extreme interest that the two populations from Nevada fall into different groups (Fig. 4). The Clark Co. (2 miles SE of Overton at 3,000 feet) population is in the same group as the Mexican and other southwestern United States populations. The White Pine Co. (5½ miles SE of Ely, at 6,100 feet) population in contrast is grouped with the other United States populations. The explanation for this is found in the fact that the Clark Co. locality is in the Colorado River and represents a northernmost extension of the same group that is found in southern California. The more northern population of White Pine Co. is essentially isolated from southern Nevada since it is located in one of the closed drainage sys-

tems of the Basin and Range physiographic province, and apparently is more closely related to the Rocky Mts. populations. If further evidence is required it may be stated that the morphology of the specimens from these two localities was studied and clearly substantiate the separation of the two Nevada populations (Table V). The entire southern tip of Nevada is in the Lower Sonoran life zone and marks the northernmost boundary of many vertebrates: *Gopherus*, *Dipsosaurus*, *Sauromalus*, *Heloderma*, *Arizona*, *Bassariscus*, and *Peromyscus eremicus* to name but some of the forms (see Stebbins 1954 and Hall 1946). Linsdale (1940) considered the Clark Co. frogs as the distinct species *Rana onca* and *R. fisheri* and the northern Nevada forms as *R. pipiens*.

The validity of the two groups of populations of *R. pipiens* as demonstrated in Figure 4 may be substantiated somewhat further. First, it must be emphasized again that there is a correlation of the H/L value and the mean temperature of the coldest month within each group. Both groups show an increase in the H/L value with the decrease in environmental temperature. Furthermore it is possible to demonstrate that there are directly comparable temperature climates in both groups. In Figure 5 the mean monthly temperatures for two localities from each group have been plotted and clearly show similar monthly temperature relations. This comparison could be strength-

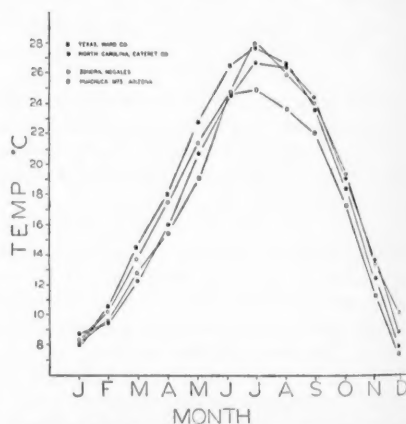


Fig. 5. Mean monthly temperatures for four localities having similar temperatures. Data obtained from United States Department of Commerce (1930) and Contreras (1942).



ened if more populations from the southeastern region of the United States had been available. It may also be stated that the high H/L value localities in Mexico and southwestern United States are all characterized by lower winter temperatures than many of the southeastern United States localities. It would appear at first glance that the mean temperature of the coldest month is a relatively meaningless measure for an aquatic animal such as a frog. Consequently it should be made clear that the mean temperature of the coldest month is merely a convenient measure of the severity of the entire winter season. The correlation of the H/L value with the mean temperature of the coldest month was actually to be expected since the severity of the winter is directly correlated (when other factors are equal) with latitude and altitude. The mean temperature of the coldest month may be considered as a measure of the intensity of the winter. Another measure of the severity of the winter season is the duration or length of the winter. If it is assumed that the H/L ratio is correlated with the severity of winter, then we must expect the H/L ratio to show the same correlation with the length of the winter season as with the mean temperature of the coldest month. (Since both of the parameters are related and are measures of the severity of the winter.) The length of the winter may be measured by the mean number of frost free days; the greater the number of frost free days, the shorter the length of the winter. The mean number of frost free days for a locality is the average number of days between the last freezing temperature in the spring and the first freezing temperature in the fall. This measure has been calculated for United States localities (U. S. Department of Agriculture, 1941), but is unfortunately not available for Mexican localities.

An estimate of the mean number of frost free days can be obtained for the Mexican localities by the use of an empirically derived formula utilizing the records of the extreme minimum monthly temperatures:  $(30 \times M) + 35 = \text{mean number of frost free days}$ . M is the number of months from (and including) the last month in the spring that has ever had a freezing temperature to (and including) the first month in the fall having had a freezing temperature. This formula was derived from

50 Arizona, New Mexico, Northern Florida, South Carolina and North Carolina localities for which the mean number of frost free days was known. The mean deviation of the estimates from the known mean number of frost free days was  $\pm 12.6$  days for the 50 localities. By the use of this formula the mean number of frost free days was estimated for four of the cold winter localities in Mexico. This estimate was not made for the subtropical localities since the mean number of frost free days for such localities may not be significant due to the very great variation in the number of frost free days from year to year.

The H/L ratio has been plotted against the number of frost free days in Figure 6. Essentially the same grouping exists as in the case of plotting the H/L ratio against the mean temperature of the coldest month.

All the above facts serve to obviate the possible criticism that the two groups are separated only because the southwest and Mexico have mild winters while the rest of the United States has relatively more severe winters.

It might now be asked if there is any explanation for the existence of the two different groups of populations in regard to the correla-

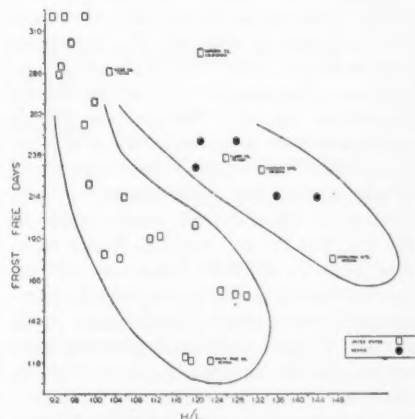


Fig. 6. The mean H/L values plotted against the mean number of frost free days. Data for the United States localities and for Nogales were obtained from United States Department of Agriculture (1941). The values for the other Mexican localities were estimated by means of the formula described in the text. All the localities listed in Tables I and II are plotted with the exception of Canada, Idaho, Wyoming, Coahuila, Tamaulipas, the San Luis Potosi localities, the Puebla localities, El Chico, Hidalgo, and Velasco, Hidalgo.

tion of the H/L value and temperature. What appears to be the most reasonable explanation is that the two groups represent historically distinct races. That is, that the Mexican and southwestern populations have evolved in partial isolation from the other North American populations. A test of this hypothesis would be provided by a detailed morphological analysis of the two groups. If such a study yielded other morphological characters that have the same distribution pattern as the H/L ratio, then the hypothesis would be supported.

There is available preliminary morphological evidence. Thus the morphology of the two Nevada populations clearly substantiate their falling into separate groups (Table V). Furthermore, the vestigial oviducts that are characteristic of the males of some populations of *R. pipiens* partially support the geographic distribution of the two groups here suggested. In general the Mexican (Ruibal 1955) and southwestern populations of *R. pipiens* are characterized by having males with vestigial oviducts in populations with a low H/L value (approximately 1.00), while the populations with high H/L value are devoid of vestigial oviducts in the males. In contrast the other North American populations have a vestigial oviduct associated with high H/L values (see map in Moore, 1944). One of the notable exceptions is the case of the southern Florida populations (op. cit.). The southern Florida populations have a vestigial oviduct and low H/L values. The northern Florida populations also have a low H/L value but lack vestigial oviducts in the males. Of special interest is the fact that the two southern Florida localities (Dade Co. and Palm Beach Co.) have the populations that clearly overlap into the Mexican and southwestern United States group when the H/L value is plotted against the mean temperature of the coldest month (Fig. 4). The other Florida population that is close to overlapping is from central Florida (Pinellas Co.). The northern Florida localities, that are devoid of vestigial oviducts in the males, do not overlap. This may therefore not be an overlap of the two groups, but rather an indication that the southern Florida populations belong in the same group as the Mexican and southwestern populations.

It is therefore tentatively suggested that the southern Florida populations of *Rana pipiens* are more closely related to the populations from Mexico and southwestern United States. For the moment the only morphological evidence in support of this is that these populations are characterized by having vestigial male oviducts associated with a low H/L value. It is obvious that this hypothesis involves the assumption that the southern Florida, southwestern United States, and Mexican populations were once continuous.

#### SUMMARY

1. A numerical value of the shape of the snout in specimens of *Rana pipiens* was obtained by means of the H/L value: a ratio of two measurements of the snout.
2. The H/L value was found to be a clinal character of the different populations of *R. pipiens*. The H/L value is directly correlated with the latitude or the altitude of the locality. It is also correlated with the environmental temperature, as expressed by the mean temperature of the coldest month of the year and the mean number of frost free days in the year.
3. The same character also demonstrates evidence of a clinal nature in other species of the genus *Rana*.
4. The developmental basis of the H/L value was tested for two Mexican populations and appears to be a genetic character that is polygenic.
5. The populations of *Rana pipiens* in North America appear to fall into two major groups in respect to the correlation of the H/L value with the mean temperature of the coldest month. One group consists of the populations from Mexico, southern Texas, southern Arizona, southern California, and southern Nevada. The other group comprises the other populations of the United States and Canada.
6. The populations from southern Florida may be representatives of the same historical group as the Mexican and southwestern United States populations.

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## Population Structure and Homing Responses in the Pacific Tree Frog

DAVID L. JAMESON

SEVERAL workers have contributed to our knowledge of the mechanism of homing in amphibians. These contributions have been reviewed by Bogert (1947). The present study attempts to develop and refine some of the techniques utilized previously and to formulate a concept of how several factors contribute to the population structure and the homing response in a semi-aquatic species, the Pacific tree frog, *Hyla regilla*.

The writer wishes to thank the many students and associates at Pacific University, Forest Grove, Oregon, and at the University of Oregon, Eugene, Oregon, who assisted in various phases of the field work. Particular thanks go to Dr. Charles Margach and to Miss Rose M. E. Myers. Dr. A. J. Bernatowicz

read the manuscript and offered many constructive suggestions.

## METHODS

The frogs were marked, each with an individual number, by clipping one or two toes on each hand and foot, as indicated below. In this system, the four fingers of the right hand were used for numbers one to four when only one finger was removed or numbers five to nine when combinations of two fingers were clipped. The fingers of the left hand were similarly used for numbers 10 to 40 when only one finger was removed and numbers 50 to 90 with combinations of two fingers clipped. The possible combinations are shown by the symbol (1) representing an entire toe and (0) a

clipped toe with the digits arranged as seen in dorsal view:

Tens	Left hand	Right hand	Digits
10	1110	1110	1
20	1101	1101	2
30	1011	1011	3
40	0111	0111	4
50	0110	0110	5
60	1001	1001	6
70	1100	1100	7
80	0011	0011	8
90	1010	1010	9

The ten toes of the hind feet from right to left were used to designate hundreds. Thus frog number 166 (in dorsal view) the outside toe (100) of the right hind foot removed, the outside and inside toes of the left hand removed (60) and the outside and inside toes of the right hand removed (6). One thousand and ninety-nine frogs can be given separate numbers by this method, and by the addition of the values of the hind toes (remove outside toes of both feet, i.e., toe number 1000 and toe number 100 giving number 1100) numbers are available for a long range study.

Slight regeneration was apparent after one year, but this was not sufficient to obscure the markings. Frogs with missing toes were not found in ponds where marking studies were not the object of the collecting but five individuals were found lacking one forefoot. One individual was found dead the night following its original marking. The removal of two toes from each front foot did not appear to reduce the activity, agility, or survival of frogs in the laboratory and is believed to be responsible for very few of the unrecovered frogs.

In a large pond in Washington County, Oregon (Thatcher Road Pond), 920 frogs were marked, measured, released and some recaptured in 1953 and 1954. The pond was divided into several portions and the data were recorded separately for each area to obtain information about home ranges, migration and normal movement of individuals. On April 3, 1954, frogs were removed 1000 yards south of the pond to another pond in order to determine whether or not they would return to the original pond.

Four ponds in Lane County were utilized in the spring of 1954 in an attempt to find out

how much of the homing phenomenon was an auditory response to the breeding chorus and how much could be attributed to familiarity with the surroundings. Frogs were moved from one pond to another, and returns to the original pond were noted. The data for each of the ponds were kept separate so that normal movements within and between the ponds could be ascertained.

#### ENVIRONMENTAL CONDITIONS

The prevailing western, warm, moisture-laden, winter winds which cross western Oregon are responsible for humid marine winters. Cloud cover is almost complete from December to June and the light but persistent rain of these months is broken mostly by heavier, and warmer rains, or by dense radiation fog. The northwesterly summer winds are typically lacking in moisture and the summer climate is warm and dry. In the Willamette Valley the mean average temperature is 50–55°F (Jan. avg. 39–49°F; July avg. 65–66°F). The daily range is typically about 20°F. The maximum is seldom more than 100°F, the minimum seldom less than 0°F. The mean annual precipitation is 44–45 inches.

#### STRUCTURE OF THE BREEDING CHORUS

In late summer Thatcher Road Pond recedes to an east-west drainage ditch which is about 75 yards long, 10 feet wide and 4 feet deep with an enlarged deeper portion at the east end. The winter rains fill the pond causing it to overflow into the adjoining pasture land until it is some 50 yards wide, and from 1–3 feet deep in the overflow area. At this time most of the bottom of the pond is covered with a rather dense growth of bunch grasses which extend above the surface of the water forming cover for the frogs. Late in spring algae invade and cover the surface of the pond. During the breeding season of the Pacific treefrog (Jan. 7 to June 6 in 1953; Dec. 16 to June 14 in 1954) the lack of vegetation in the drainage ditch may have been responsible for separating the frogs of the breeding chorus into northern and southern groups.

Of the 373 frogs marked and released in or near the pond between April 1 and May 12, 1953, 173 frogs were recaptured during the same time. Of these recaptured frogs, 144 were found on the same side of the pond as before,

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24 on the opposite side from the original place of capture, and five frogs crossed the ditch, were captured and released, recrossed the ditch and were recaptured again. Twenty-seven of the frogs were recovered in 1954 in the same half of the pond as found in 1953, whereas eleven others had moved.

Although the exact movements of every frog were not recorded, observations on 16 males marked on April 13, 1953, give some insight into individual movements. Attempts to recapture these frogs were made on April 14, 15, 20, 21, 23, 27, 28, and 29. One of these frogs was recovered nine times, another eight times, seven were recovered on four occasions, three were recovered three times and four were recovered twice. One of these frogs was found during the daytime on the bank of the pond about 25 feet from the original nocturnal collecting site. With this exception none of the 16 frogs was recovered more than six feet from the original marking site and most of the frogs moved only a few inches. From these data there seems little doubt that the frogs tended to remain in a particular part of the pond.

The Proportional Index (Allee et al, 1949, p. 269) was used to estimate the total number of male frogs in the pond. Only male frogs were used in the calculations because females were not found long at the breeding sites. Three nights (April 27, 28, 29, 1953) were used as precensus nights and 166 frogs were collected and marked. During the nights of May 4, 5, and 6 the census was taken and 102 marked and 194 unmarked frogs were captured. Thus:

No. marked individuals recovered in census

No. individuals marked in precensus

$$= \frac{\text{No. unmarked individuals obtained in census}}{\text{total number of unmarked individuals at end of precensus}}$$

$$\frac{102}{166} = \frac{194}{X}$$

$$X = 316$$

and approximately 484 (166 + 316) frogs were in the pond. Frogs marked and removed from the pond as a part of the homing study (see below) are here considered as unmarked frogs.

Three consecutive nights were found to be the maximum for efficient collecting. Many of the individuals become light shy; results of the

third night were never as satisfactory as those of the first two nights and those of the fourth night were always very meager. The pattern of working the same three consecutive nights of each week, allowing a four day rest between collections was found satisfactory. Effort was made to collect in all parts of the pond each night, but some parts of the pond were rather inaccessible.

The general assumptions of the use of the Proportional Index method to determine the numbers of individuals in a population are as follows: (1) precensus marked frogs redistribute themselves at random in relation to the unmarked individuals, (2) unmarked frogs are captured with the same ease as marked frogs, and (3) no births, deaths or migrations occur in the population. The frogs are not naturally distributed at random but occur in groups in the shallower parts of the pond. Some frogs are noticeably more light shy than others and undoubtedly many frogs were sufficiently light shy that they were never seen. Births may be ignored for this study but deaths due to predation (Jameson, 1956) and migrations are additional sources of errors. The Proportional Index is usually considered satisfactory if the precensus sample constitutes at least 10 percent of the final estimate. In this case the precensus sample (166 frogs) was more than 30 percent of the final estimated population size.

No census was made in 1954. However, there was little doubt that more frogs were present in the pond than in 1953 as 630 new

frogs were captured in two nights (April 3, May 7) and 38 frogs from 1953 were recovered.

#### HOMING RESPONSE

In addition to the 166 frogs marked for the purpose of estimating population size, other frogs were marked and moved to study pos-



sible homing behavior. On April 27, 1953, 30 frogs from the north part of the pond were moved 300 yards south of the pond. The release locality was approximately 30 feet higher than the pond and an orchard occupied the area between. On April 28, 29 and May 4, 5, 6, fourteen of these frogs were recovered in the north part of the pond, seven in the south part and nine were not recovered. On April 29, 1953, 53 frogs from the south part of the pond were moved 300 yards north of the pond. The release point was approximately 35 feet higher than the pond and the area between was a plowed field. On May 4, 5 and 6, six of these frogs were recovered in the north part of the pond and 29 were recovered in the south part of the pond. Eighteen frogs were not recovered. Thus 43 of the 56 frogs which were recovered reached the home areas while 13 stopped at the opposite side of the pond. Fifty-six (66.3 percent) of 83 frogs removed were recovered in the pond. Only 61.5 percent (102 of 166) unmoved marked frogs were recovered. Thus a greater percentage of moved than unmoved marked frogs were recaptured. Perhaps the recoveries of returned frogs on each side were proportional to the actual returns on each side.

On February 27, 1954, 18 frogs marked in 1953 were recovered in Thatcher Road Pond and 277 new frogs were marked. On April 3, 1954, 20 frogs from 1953, 41 frogs from 1954 and 353 new frogs were captured. These 414 frogs were released 1000 yards south of this pond in another pond (High School Pond) where there was already a breeding chorus of perhaps 100 treefrogs. On May 7, 1954 frogs were collected at both of these ponds. Only three of about 25 calling frogs were captured in the High School Pond; none of these was marked. Forty-three of approximately 200 calling individuals were captured in Thatcher Road Pond. Thirty-one of these frogs were unmarked. Seven (3.0 percent) of the marked frogs were of the 236 (277 marked February 27 less the 41 moved April 3) marked in 1954 but unmoved. None of the frogs marked in 1953 was recovered. Five (1.2 percent) of the marked frogs were of the 414 which were moved to the High School Pond. They had left the breeding chorus at the High School Pond and in one month or less presumably crossed 1000 yards through plowed fields,

across lighted streets, among houses to their home pond; four of the five returned to the same side of the pond where originally captured.

A slightly more elaborate procedure was utilized in Lane County in 1954 in order to determine whether the frogs were homing in response to the breeding chorus or if some additional factors were involved.

Ninety-eight frogs in three temporary ponds were marked on ten collecting nights in early January, 1954. These ponds are each about 20 yards long and 3 yards wide and are parallel to each other. The east and west ponds are about 45 yards apart and the center pond is approximately midway between them. These ponds are referred to as ponds A1, A2, A3 from west to east. Fifty-three frogs were marked in a semi-permanent pond which is referred to as pond B, 125 yards north.

Forty-two frogs were recovered in nine nights of collecting in ponds A1, A2, A3. Thirty-two of these were recovered in the same pond, eight in an adjoining pond and two moved from pond A1 to pond A3. None of the frogs marked in the A ponds moved to pond B. Twelve frogs marked in pond B were recovered, 11 in pond B and one in pond A2. These data indicated that during the period of observation some of the frogs tended to remain in a limited area and that there was very little movement between ponds A and pond B.

On January 28, 12 frogs from pond B were placed in pond A2. On seven collecting nights in February, five of these were recovered in pond B, one in pond A1 and one in pond A2. Twenty-four frogs from ponds A1, A2, A3 were placed in pond B on January 28. Fifteen of these were recovered during February in the A ponds and only one in the B pond.

Thus 23 (63.9 percent) of 36 moved frogs were recovered. Fifty-four (35.8 percent) of 151 unmoved marked frogs were recovered. At first glance it would appear unlikely that one would obtain almost twice as many recoveries from the moved frogs as from the unmoved frogs. There were large breeding choruses within one-fourth mile to the north and south and within one-half mile to the east of the experimental area. Probably many of the 97 unrecovered, unmoved frogs were transients moving through the temporary pond toward



the larger choruses. The 97 "migrating" frogs were marked on ten collecting nights whereas the 36 frogs which were moved were all collected on one night and would naturally include a lower percentage of transients. Three nights were spent collecting frogs from the nearby choruses, but none of the frogs marked in the experimental area was found. No attempt was made to determine the population size by the Proportional Index because of the large number of migrating frogs. Nine marked frogs were recovered in 1955 and three in 1956, all of which were frogs which had been recaptured at least once in 1954. Thus a rather permanent resident population exists in these ponds in addition to the temporary migrating frogs. The ponds dried before transformation of tadpoles in 1954, 1955, and 1956.

#### SEX RATIO

Only 22 females were marked during the study. All the females were obtained following hard, relatively warm rains. Two of them were recovered once, both on the night following the original marking; neither had mated when recaptured, possibly because of disturbance by the collectors. None of the females collected had spawned. On the night of April 12, 1954, following a very heavy rain, 34 females and three males were obtained by driving 52 miles of black-topped road in the drainage of the Long Tom River, Lane County, Oregon. All three males and 13 of the females were small individuals. These data indicate that the females respond to warm rains, move to the breeding chorus and apparently leave the pond shortly following mating.

#### DISCUSSION

In the lower elevations of the Willamette Valley during the late summer, fall and early winter the frogs reside in areas which may be a mile from the breeding sites. At this time they are found under logs, rocks, houses or any other cover where there is slight moisture. They frequently call from such places during off season rains. During winter and spring the males move to permanent or semipermanent ponds where they form breeding choruses. This movement is probably in response to a particular set of environmental conditions, in this case believed to be the first warm rains after the passing of a certain

threshold of reproductive hormonal production. At the breeding site choral patterns appear to be established and the frogs may consistently utilize the same calling sites. During the height of the breeding season they may call 24 hours a day with greater intensity during a few hours after sunset. They have been found calling in pools formed by melting snow at 4000 feet in April and at 6000 feet in June and along the coast in tidal ponds from January to March. The males call as late as August at elevations above 2000 feet. Thus the time of the breeding season is influenced by temperature and thus varies with altitude.

The distribution of breeding sites serves as a limiting factor to both occurrence and size of the frog populations. Most of the semi-permanent ponds and roadside ditches in the level flood plain of the Willamette Valley are utilized by these frogs. The ponds are typically small and the populations in them are only occasionally over 500 calling individuals and usually less than 200. The roadside ditches may have a linear chorus over several continuous miles but isolation by distance reduces the size of the breeding unit. Breeding situations are very rarely found in the dense Douglas fir forests which cover northwestern mountains. However, in both the Cascade and the Coast mountains breeding choruses are found in occasional ponds and infrequent quiet pools along the streams. Isolation by distance where the pattern of distribution is dendritic is felt to be even more effective than where the distribution is linear (Blair, 1951), and in the mountains the choruses are isolated in pools dendritically arranged.

Within the ponds the concentration of frogs is consistently found to be in shallower portions where vegetational cover is heaviest. There is obvious localization of movement of the frogs as shown by both local recapture and by homing studies. The apparent occurrence of a distinctive calling pattern associated with the localized movements found in the 16 individuals studied may indicate the presence of a definite spatial arrangement of the males somewhat as found in the green frog, *Rana clamitans* (Martof, 1953). Other evidence of territoriality was not noted.

Male *Hyla regilla* appear to enter the ponds and remain for several months, though not necessarily for the entire breeding season.

There appears to be a gradual turnover in male individuals, some appearing and leaving early and others appearing and leaving late. The time of appearance was not correlated with the size of the individuals. All 38 of the frogs marked in 1953 and recovered in 1954 were marked between April 1 and April 14, 1953. Eighteen of these were recovered on February 27, 1954, twenty on April 3, 1954 and none on May 7, 1954.

Growth data (Jameson, 1956) indicates that sexual maturity may occur in one year. The small number of returns (38 of 373) over a one year period indicate a very rapid turnover in the male population.

A few females begin to move to breeding sites a few weeks after the males and some will be found in the ponds following warm rains until the middle of May. It may be that the females' hormone production is inherited in such a way that some individuals are always ripe at any one time in the spring and that warm rains provide the final adequate stimulus. The female enters the pond at one point and the opportunity to mate may be with only a few of the nearer males. The size of the breeding population at any one time is limited by the number of females present at that time rather than the number of calling males. During the entire breeding season the number of females may equal the number of males.

It is apparent that the populations of the Pacific treefrog are divided into small units in time and/or space by the localization of the breeding situation, the arrival and very brief stay of the female, with her presumed once per year mating, the time of occurrence of the male in the pond, his localization of movement and possible spatial arrangement, the high rate of turnover which results in an almost complete change in the population each year and perhaps by sexual selection. The study of juvenal dispersal (Jameson, 1956) indicates that there is a rather low rate of distribution of genes from one pond to another thus increasing the amount of isolation between breeding populations. The low gene flow between these breeding units would tend to increase the possibilities of both non-adaptive and adaptive differentiation which would be expected to result in a rapid evolution of the local populations.

Previous workers have suggested several

factors as possible explanations of the homing response. These factors include random radial scattering, memory, optic, olfactory, auditory and kinaesthetic senses and the presence of special sense organs. These have been discussed in some detail by Bogert (1947). Since it is probable that the homing instinct is variously developed in different species we shall limit our consideration to what we have found in the Pacific treefrog in Western Oregon.

The percentage of recovery of the moved frogs (66.3 percent) when compared to the recovery of unmoved animals (61.5 percent) immediately discounts the possibility of mere random radial scattering from the point of release. Memory of certain landmarks, obtained mostly by visual sense, cannot be completely eliminated as an explanation of a portion of the results. The home range of each individual while a member of the breeding chorus is very small. However, the activity of non-aggregated individuals is largely unknown. Fall and winter ranges in some cases are several hundred yards from breeding sites. Calls are repeatedly heard from the same place during this time which would indicate that both the "breeding" range and the "non-breeding" range are each rather small even though far removed from one another. It is possible, though certainly not probable, that the five individuals which returned over 1000 yards to the home pond were familiar with all or a portion of the terrain they covered. This familiarity would have been obtained at least four months previous to the homing movement. It is questionable that frogs retain impressions for so long.

In addition to the nocturnal calling range a somewhat larger day-time range which is frequently at a different part of the pond appears to exist at the breeding site. Thus the frogs are probably more familiar with the pond than the size of the calling range would indicate. This may explain the ability of the Lane County frogs to return to a particular pond (one of the A ponds) or of the Washington County frogs to find the proper part of the pond once they had reached the general vicinity.

Olfactory and kinaesthetic senses would seem unlikely explanations for the data obtained. The first generally assumes that the frog smells aquatic situations and the tend-

ency of the frog to leave one aquatic situation for the home situation would require that the frog could distinguish the smell of the home pond. The frogs in Washington County may have responded to some extent to the general downhill terrain but in the Lane County study the area was essentially level with a slight (2-3 foot) rise between the A ponds and the B pond.

The presence of "special" sense organs or hormones can be neither eliminated nor demonstrated by the present study. Undoubtedly hormonal activity is responsible to a greater or lesser extent for the initiation of the original movement to and from the "breeding" site. Further activity by the same reproductive hormones would not seem to explain the tendency of the frogs to return to the breeding site when they were moved from the home pond. There is no evidence for a special hormone or sense organ.

An auditory response to calling individuals would explain the return of frogs to the breeding pond when removed to the orchard or to the plowed field. Acoustical cues would not explain the movement from one breeding site to the home site unless the frogs are able to distinguish the calls which come from the home pond from those calls in other ponds in the area. The presence of distinctive call patterns which occur repeatedly between some individuals may lend support to this last assumption. Certainly the work of Martof (1953) on *Rana clamitans* would indicate that the green frog is aware of the presence and position of particular individuals in the immediate vicinity. Martof attributed this awareness in the green frog to its ability to recognize the call of other individuals in the area. In the treefrogs the members of a chorus late in the breeding season are frequently found to be as much as one hundred yards apart. Thus it is not completely unreasonable to assume that the frogs can distinguish the home pond or a portion thereof by recognizing the particular individuals in the home pond. This of course requires considerable memory and could be partly tested by keeping the frogs away from the home sites for various lengths of time.

It is no more reasonable to assume *prima facie* that a frog can identify a particular pond by sound than that he can by smell. However,

there is some evidence that the frogs may be able to recognize distinct and particular sounds, and as yet there is little evidence that the frogs possess such critical olfactory abilities (Risser, 1914; Locher, 1927).

The auditory concept would not, however, appear to explain the return of the five treefrogs which were moved 1000 yards to a breeding site where the home chorus could only be faintly heard by human ears and at least six other choruses could be more readily distinguished. This theory would also fail to explain how some frogs return to a home site when others do not. It seems more likely that if the three or four members of a choral group were all moved to an apparently favorable site at the same time that they would tend to reestablish the choral group in the new site.

Thus no single fully adequate explanation is available for the homing responses demonstrated by the Pacific treefrog. Apparently several factors work together.

#### SUMMARY

Studies of marked populations of the Pacific treefrog were made in western Oregon in 1953 and 1954 in order to estimate the influence of several factors on the population structure and the homing response.

One hundred forty-four (83.1 percent) of 173 recoveries of marked individuals in one pond were made in 1953 in the same portion of the pond where the frogs were originally captured. Twenty-seven (71.1 percent) of 38 male frogs recaptured in 1954 were found in the same portion of the pond where they were originally marked. Individual male frogs were found typically to remain within a few feet of the same spot every night during their stay in the breeding pond. Eighty-three frogs were removed 300 yards from the pond and 43 of the 56 that were recovered were found in the same area from which they had been removed. In 1954, 414 frogs from this pond were moved 1000 yards to another pond which contained a breeding chorus. One month later none of the 414 was recovered in the release pond and five of the 414 were found in the home pond.

In 1954 three small closely adjoining temporary ponds and a nearby larger permanent pond were utilized to further check the homing responses. Forty of 42 frogs recovered were

found in the same (32) or next adjoining (8) pond. Twelve frogs from the larger permanent pond were placed in one of the smaller ponds and 24 frogs from the smaller ponds were placed in the larger pond. Three of these moved frogs were recovered in the release pond and twenty were recovered in the home pond.

Male frogs were found to go to the breeding pond in January or February and were present well past the end of the breeding season. Some males arrive and leave early, others late. The females move to the breeding choruses in response to warm rains and apparently leave the pond shortly following mating.

Olfactory, auditory and kinaesthetic senses are considered as possible contributors to the homing response in the Pacific treefrog. No single factor was found which would explain the data obtained.

The breeding population consists of a small number of individuals with a rapid rate of

replacement. The low gene flow between the geographically and seasonally isolated populations would tend to favor a rapid evolution of the various populations.

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## Herpetological Notes

A RECONSIDERATION OF THE NOMENCLATURE OF THE SMALL WHIPTAIL LIZARDS (*CNEMIDOPHORUS*) OF SOUTHWESTERN TEXAS.—Burger (1950, Chicago Acad. Sci., Nat. Hist. Misc., No. 65: 2-4) in reviewing the works of others and on the basis of his own material recognized two species of small whiptail lizards in southwestern Texas: *Cnemidophorus perplexus* Baird and Girard (1852), a species with small mesoptychial and postantibranchial scales, and *Cnemidophorus inornatus* Baird (1859), a species with relatively larger mesoptychial and postantibranchial scales. Burger implied that he was not fully satisfied with this arrangement but because of lack of material allowed it to stand.

A study of 395 specimens of the small whiptails from Terrell, Brewster, and Presidio counties, Texas, indicates that a division of these lizards into two distinct species is unwarranted. In examination of the mesoptychial scales, it was found that every possible degree of variation is present from the relatively small (i.e., almost granular) scales characteristic of *Cnemidophorus tigris* to the relatively large (i.e., almost as large as the infralabials) mesoptychials of *Cnemidophorus sacki*. The postantibranchials proved to be equally as variable and ranged from ones unenlarged or only very

slightly enlarged as in *C. tigris* to ones proportionately as large as those found in *C. sacki*. Five of the 395 specimens were found to have unenlarged postantibranchials on one arm and distinctly enlarged ones on the other. It is apparent, therefore, that the distinctions between *C. perplexus* and *C. inornatus* rest upon the extremes of a pair of continuous variants. For this reason, it seems best to recognize the small whiptails as belonging to a single rather widespread and plastic species. The name *perplexus* has priority and is the name by which the species was known for many years; so it is suggested that this name be assigned to the species and that the name *inornatus* be relegated to its synonymy.

In the past, *C. perplexus* has been placed in the *tesselatus* group of the genus *Cnemidophorus* and *C. inornatus* in the *sexlineatus* group. Inasmuch as the size of the mesoptychial scales has been shown to be a continuous variant from relatively small to relatively large, the small whiptails could possibly be placed in either group. The color pattern of these lizards, however, is very close to that found in many forms of the *sexlineatus* group and totally different from that of any form found in the *tesselatus* group. On this basis, it is suggested that *C. perplexus* be assigned to the *sexlineatus* group.

I am grateful to Dr. W. F. Blair for permitting me

to examine the specimens used in this study. All are in the Texas Natural History Collection of the University of Texas.—WILLIAM W. MILSTEAD, *Department of Biology, Sul Ross State College, Alpine, Texas.*

**BULLFROG PREDATION ON THE EASTERN SPADEFOOT, *SCAPHIOPUS HOLBROOKI*.**—Pearson (1955, *Ecol. Mono.*, 25) states, "One big gap in the knowledge of *Scaphiopus* concerns its predators." Goin (1947, *COPEIA*, (4): 275) reported predation by a southern hognose snake (*Heterodon simus*), and Carr (1940, *Univ. Florida Biol. Sci. Ser.*, 3) by several species of gulls. These reports appear to be the only mention of predation on adult *S. holbrooki*.

The stomach of an adult male bullfrog (*Rana catesbeiana*), caught October 19, 1956, in a temporary pond in a hydric hammock at Newnans Lake, Alachua County, Florida, contained two adult spadefoots. The frog had a head width of 57 mm. and a snout-vent length of 135 mm.

The two spadefoots were fully adult having head widths of 19.9 and 18.8 mm. Sex could not be determined. Two wood beetles (*Passalus cornutus*), a cricket (*Gryllus*), a wolf spider (*Lycosa*), four ants, and a small millipede were also in the stomach.

It would appear that usually bullfrogs would not exert much predation pressure on *Scaphiopus*, a burrowing terrestrial form, except perhaps when *Scaphiopus* was breeding. No breeding choruses of spadefoots were heard at the time of capture of the frog. It is possible that flooded conditions forced the spadefoots and wood beetles out of concealment. It has been noted previously that large, non-breeding ranids occupy temporary ponds where displaced non-aquatic animals might offer a ready food supply.—J. ALAN HOLMAN, *Department of Biology, University of Florida, Gainesville, Florida.*

**RECORDS OF *ANCISTRODON PISCIVORUS LEUCOSTOMA* (TROOST).**—Published records of the occurrence of the western cottonmouth in Brazos County, Texas are rare. Brown (1950, *Annot. Check List of the Reptiles and Amphibians of Texas*, Baylor Univ. Studies: 214) does not list this snake from Brazos County, although the county is included in the distribution given for this snake. Peterson (1950, *Amer. Midland Nat.*, 43 (1): 157-164) records two specimens collected near College Station, Brazos County. As one familiar with the general range of this subspecies would suspect, Peterson's records cannot be interpreted to mean that the cottonmouth is rare in the county. Indeed, it is very common. James Baldauf, Ernest Tanzer, and several other youths living in College Station have regularly collected and observed the western cottonmouth along Whites Creek, a few

miles southwest of College Station, Brazos County, Texas. Some of these specimens now repose in the private collections of these ardent herpetologists; in addition, the collection of the Dept. of Wildlife Management, A. and M. College of Texas, contains several specimens collected in Brazos County by other collectors.

On May 18, 1955, James Baldauf collected a 615 mm. western cottonmouth from the August Simmons ranch, 11 miles west of Mason, Mason County, Texas. Brown (*op. cit.*) gives the Texas distribution of the western cottonmouth as "Eastern Texas west to Bexar, Burnet, and Grayson counties." Reports of this snake from counties farther west (Valverde) need confirmation, according to Brown. Smith and Sanders (1952, *Texas Jour. Sci.*, 4 (2): 214) report a specimen taken from Kimble County by Mr. I. Lester Firschein and Dr. Charles E. Burt. Although this Kimble Co. specimen has been lost, according to Smith and Sanders, the record was re-established when Ramsey (1948, *Herpetologica*, 4: 228) reported the snake from the same county.

On October 24, 1956, Mr. R. F. McAllister, Dept. of Oceanography and Meteorology, A. and M. College of Texas, collected a western cottonmouth from a point in the Gulf of Mexico about 1½ miles southeast of South Pass Jetty of the Mississippi Delta in Louisiana. The 760 mm. specimen was taken from water having an approximate current velocity of 0.7 knots/hour toward the south. Reports of these and other snakes in brackish waters are not uncommon, and their habit of crossing rivers is well known. The present report indicates how a reptile exhibiting such habits might either be swept out into the open Gulf or reach such waters by getting lost while crossing wide areas such as the southern mouth of the Mississippi River.—RICHARD J. BALDAUF, *Dept. Wildlife Management, A. and M. College of Texas, College Station, Texas.*

**NOTES CONCERNING TURTLE HATCHLINGS.**—Many workers have commented upon the fact that the hatchlings of some turtles remain within the nest during the fall and winter and emerge the following spring. From April 17 until May 2, 1942, Hartweg (1944, *COPEIA*, (1): 20-22) found hatchling *Chrysemys picta marginata* that were evidently leaving nests of the previous year in the vicinity of Ann Arbor, Michigan; the nests were not located. In a later paper (1946, *COPEIA*, (4): 255) he reported that eggs deposited June 18, 1944 produced hatchlings that emerged from the nest about March 25, 1945, an interval of 280 days.

During field studies of *Chrysemys picta marginata* from the spring of 1953 until the early summer of 1955 at the Edwin S. George Reserve, near Pinckney, Livingston County, Michigan, I observed no hatchling painted turtles during the fall.



The earliest dates on which they were seen were May 6, 1953, April 20, 1954, and April 19, 1955. A female *Chrysemys* observed depositing eggs on May 24, 1955 had a length (straight line distance along the vertical shields) of 12.3 cm. The nest site was immediately covered with a hardware cloth screen after the completion of nesting and was subsequently checked at intervals for signs of emergence of the hatchlings. No turtles left the nest during the fall of 1955. The site was checked by me on March 31 and April 1, 1956 and by Mr. Russell Mumford on April 28, 1956 but no young were found. I found seven hatchlings beneath the screening, May 4, 1956. The time elapsed between deposition of the eggs and emergence from the nest was between 340 and 346 days. Since nesting during the 1955 season was about 2 weeks in advance of other years, spring emergence does not appear to be caused by a late egg-laying season.

On September 27, 1953, a hatchling *Emys blandingi* was collected by Dr. Irving Cantrall on the lawn of his home on the Reserve. The animal was heading southward toward some small ponds. An egg tooth (caruncle) was present. On September 6, 1954, I found a second hatchling on a dirt road in the middle of an open field. Its length was 2.7 cm. and a caruncle was present.

A partly uncovered nest containing the eggs of *Chelydra serpentina* was found in mid-June, 1953, and it was immediately covered with dirt. On October 10, 1953, I uncovered the nest and found a single hatchling (length = 2.5 cm.), an infertile egg, and the remnants of 6 other eggs from which hatchlings had already emerged and left the nest. During the afternoon of October 25, 1953 two small *Chelydra* were found within 20 yards of each other on a dirt road near a swamp on the Reserve. No nest was found. The temperature was 53°F. The minimum temperature recorded in the area the preceding night was 44°F. and the maximum for the day was 57°F. Evidently cool temperatures do not inhibit emergence from the nest. Another nest was found June 5, 1955 and immediately covered with hardware cloth. It was dug up on August 24, 1955; each of the twenty eggs had produced a turtle. Sixteen had completely escaped from the egg shell, and the other four had partly done so. The average weight of the hatchlings was 8.4 gms., the extremes 9.1 and 7.3 gms. The lengths averaged 2.6 cm. with extremes of 2.7 and 2.4 cm.

The turtles from this last clutch were kept in captivity so that the time required for the caruncles to drop off could be determined. All caruncles were present for the first four days after the turtles were dug up. Four had disappeared by the fifth day, seven more by the seventh day, one more by the eighth, two more by the tenth, two more by the twelfth, three more by the fourteenth, and the final

one by the seventeenth day. Such information conceivably can be used to estimate the age of the hatchling during the earliest period of its life.

Risley (1933, Papers Michigan Acad. Sci., Arts, Lett., (17): 685-711) found that the young of *Sternotherus odoratus* evidently left the nest during the fall at Whitmore Lake, 12 miles north of Ann Arbor, Michigan. He collected many young within the egg during the spring, but the turtles had failed to survive the winter.

The scanty data from Dr. Hartweg's papers and from my observations on the George Reserve suggest that *Chrysemys* regularly overwinter in the region of Ann Arbor, whether the nesting season is early or late. Other authors have made similar suggestions for other areas. Dr. Hartweg has suggested that the earth may be too hard for the hatchlings to dig through during the fall, and that they must await the spring rains, but this does not seem to apply to my observations since there was 2.9 inches of rain during September and October, 1953, 10.3 inches for the like period in 1954, and 3.8 inches for October 1955. Also, *Emys blandingi* and *Chelydra serpentina* are able to leave the nest cavity during these same periods. Perhaps overwintering is a behavioral adaptation of *Chrysemys* enabling it to survive in more northerly regions.

I am indebted to the late Professor J. Speed Rogers and to Dr. Irving Cantrall for permission to use the facilities of the George Reserve. Mr. Russell Mumford kindly checked nest sites for me.—OWEN SEXTON, *Edwin S. George Reserve, Pinckney, Michigan.*

NOTES ON THE PYGOPODID LIZARDS, *LIALIS BURTONI* AND *L. JICARI*.—Little is known about the habits of the pygopodid lizards, *Lialis burtoni* and *L. jicari*. Loveridge (1945, Reptiles of the Pacific World: 101) hazarded a guess that they were inhabitants of long-grass country. Bellairs and Underwood (1951, Biol. Rev. Cambridge Phil. Soc., 26: 225), following Camp (1923, Bull. Amer. Mus. Nat. Hist., 48: 330), suggested that *Lialis* species might be surface dwellers in spite of a snake-like build, and remarked on the lack of information concerning pygopodids generally. The following observations on *Lialis* might therefore be of interest.

*Lialis burtoni* was found to be fairly abundant at a locality about eight miles northeast of Port Moresby, Papua, during 1943. The locality is within the "dry belt" of southern Papua. This general region is one of rolling hills and occasional rocky outcroppings, with scattered swampy ponds in lower places. Most of the area, with the exception of pond margins and rocky hillcrests, is densely covered with tall *kunai* grass. The vast stretches of grassland are dotted with eucalyptus and occasional



curlybarks (*Melaleuca*); other trees are few. *Lialis burtoni* appeared to be confined to this savanna association.

Soldiers cutting grass frequently encountered *Lialis burtoni*. I saw no evidence that this lizard burrowed in the ground; it was always flushed from grassy cover. The species appeared to be crepuscular and nocturnal. Between dusk and 9:30 P. M., specimens sometimes crawled into the army encampments, coming from the surrounding grassland.

On December 29, 1943, I collected a female at the aforesaid locality. It measured 187 mm. in snout-vent length and 362 mm. in total length. The tail tip had been regenerated. The lizard contained two eggs ready for deposition. The egg shells were remarkably tough and leathery. Each egg was about 31 mm. in length and 10 mm. in maximum diameter.

The second species, *Lialis jicari*, was fairly abundant at Nadzab, in the Markham Valley of Australian New Guinea, during 1944. At this locality the valley floor was covered by *kunai* grass, with scattered patches of dense forest. *Lialis jicari* appeared to be confined to the grassland.

This lizard was collected by a novel method. Five tribes of the area stage extensive fire drives, the Papuan hog being the main quarry. At intervals during the dry season, the natives cut scattered piles of *kunai* grass. These piles are arranged in a great arc, the ends of which may be a quarter-mile apart. The open side of the arc faces away from the prevailing winds, and a narrow strip of grassland is cleared between the ends of the arc. When wind and weather conditions appear satisfactory, the dead grass is set ablaze. Contrary to what might be expected, the crescent-shaped line of fire advances rather slowly. It is followed and preceded by beaters who flush the hogs and other game from small coverts where they might otherwise find shelter. So slowly does the fire advance that even the more sluggish reptiles are able to stay ahead of it, and some of them are thus forced into the cleared area. They are not valued by the natives, and so may be collected. Commonest reptiles thus driven from the grassland include *Lialis jicari*, pythons of the genus *Liasis*, and the death adder, *Acanthophis antarcticus*.

Whenever fire drives were staged, eagle-kites (*Haliastur indus*) always made their appearance. These birds would dive into the smoke catching the grasshoppers that flew up in advance of the blaze. Sometimes they would dive to the ground and strike at a small snake or lizard. Probably they catch a few *Lialis jicari*.

Both *Lialis burtoni* and *L. jicari* are said to be variable in color. Some of this variation may prove to be of taxonomic significance. The coloration of *L. jicari* seems to have been described mostly from preserved specimens. The pattern of the species in the Nadzab area is so remarkable as to merit re-

description from a living example. It consists of narrow stripes beginning on the head or nape and continuing onto the base of the tail. Down the midline of the back is a stripe of dull grayish-brown with fine black punctations. This stripe involves one scale row on each side of the body. Below it is a silvery-gray stripe with black punctations, involving two scale rows. Below this is a light greenish-gray stripe, with black punctations, occupying one scale row; every other scale of this stripe bears an irregular, blackish blotch near its tip. Next in order down the side of the body is a silvery-gray stripe with black punctations, involving one scale row. Below this is a bluish-gray stripe with black punctations, involving two-thirds of a scale row. The remaining third of this row, and half of the next row, bear a stripe of dull white with black punctations. Next there is an immaculate cream stripe involving two half-rows. This cream stripe is separated from the dull white one above it by a fine line of black punctations. Below the cream stripe is another stripe, a half-row in width, of dull white with black punctations and a pair of black markings like parentheses on each scale. The next scale row bears four very narrow stripes, the first white, the second black, the third gray with black punctations, the fourth white; each of these stripes occupies a quarter of a scale row. Next is a pinkish-gray stripe one scale row in width. Ventrad of this is a white stripe occupying a little less than a quarter of a scale row. Below this white stripe is a pinkish-gray one, a little more than a quarter of a scale row in width. Finally there is a midventral stripe of bright salmon, involving a half-row on each side of the body. The last stripe, unlike all the others, is not straight but zigzag; there is a circular white spot just within each apex of this zigzag line. Thus the pattern of *L. jicari* consists of 15 stripes down each side of the body, plus a middorsal and a midventral stripe. In preservative the various pastel hues become uniformly grayish; the darker markings are the only ones to remain evident, and these only as dull stripes and rows of punctations.

The above description was taken from a female *Lialis jicari* (No. 16492 in the collection of E. Ross Allen and the author) measuring 272 mm. in snout-vent length and 520 mm. in total length. The tip of the tail has been regenerated. The lizard contained two tough-shelled eggs, each measuring about 29 by 15 mm. This specimen was collected some time between May 1 and August 31, 1944.

In *Lialis jicari*, the teeth are remarkably fine and thin, scarcely visible without magnification; the snout is exceedingly long and slender. These characteristics imply some dietary specialization. The stomach of the above-mentioned female contained a yellowish, amorphous mass in which I could distin-

guish no chitinous fragments of insects or other arthropods.

*Lialis jicari* was observed only during fire drives. Since the pupil of its eye is vertically elliptical by day and rounded at dusk, I presume the lizard is crepuscular or nocturnal like its congener.—WILFRED T. NEILL, *Research Division, Ross Allen Reptile Institute, Silver Springs, Florida.*

A SCHOOLING OF LEATHERBACK TURTLES, *DERMOCHELYS CORIACEA CORIACEA*, ON THE TEXAS COAST. A concentration of leatherback turtles, *Dermochelys coriacea coriacea* Linnaeus, was observed in the Gulf surf along a thirty mile line extending north from Port Aransas, Texas. An estimated 100 individuals were seen throughout the area and were approximately 75 yards from the beach. Observations and identification were made from a low flying airplane on December 17, 1956.

An extremely dense school of the cabbage head, *Stomolophus meleagris* L. Agassiz, extended through the same area, and the turtles were most numerous where these jellyfish were most dense. No turtles were observed on the beach. No attempt was made to locate nests or to collect specimens due to bad weather which closed in shortly after the turtles were located. The beach along this area is a deserted one and is formed by St. Joseph and Matagorda Islands.

All leatherbacks observed ranged in carapace length from  $3\frac{1}{2}$  to 6 feet.—TERRANCE R. LEARY, *Texas Game and Fish Commission, Rockport, Texas.*

OBSERVATIONS ON MATING IN THE CORN SNAKE, *ELAPHE GUTTATA GUTTATA*.—Courtship and mating behavior in two captive corn snakes collected in the Florida Everglades are reported. The observations were made at Dayton, Ohio.

A female (1087 mm. in snout-vent length) and male (962 mm.) were received in May, 1955. They were placed together on May 26, 1955 (8:30 PM) and a few moments later courtship began. Copulation occurred then and again the next day.

The male placed his ventral surface along the dorsal surface of the female with his head near hers. As she moved about the cage, her forward movement seemed to excite him. Although her movements were quick and deliberate, he maintained his position. He moved his body into numerous undulating curves that followed the contour of her body. At the same time his lower sides twitched along their full length. Ripples in this region were numerous and fast and, along with a jerky movement of the entire body, seemed to form the preliminary courtship.

The male moved his body forward along the back of the female, and as he did so she became more active. He moved his tail posteriorly along the lower one-fourth of her body. With a sudden jerk, his tail entwined hers and the hemipenis was inserted. After union was effected the male again aligned his body with that of the female. The hindquarters of both snakes, from slightly anterior to the anus to the tip of the tail, were occasionally elevated and then slowly lowered. The animals were moved around by hand for photographic purposes, but copulation continued. Copulation occurred again in the morning and afternoon of the second day, lasting fourteen and nine minutes, respectively. Each of the three observed meetings was less vigorous than the preceding one.

On July 2, 1955, the female laid eleven eggs, approximately 32 mm. long, which were confined between a few coils of her body. Eight of the eggs adhered and three were unattached. Three of the eggs were found hatching on August 29. On August 30, one hatchling emerged in the morning and a second in the afternoon. The third emerged on September 1. It had a swelling which started a little anterior to the anus and extended for one-half the tail length. This deformity may have been due to suboptimal moisture conditions (Lynn and Ulrich, 1950, *COPEIA*, 4: 253-62). Two of the remaining eight eggs were infertile. None of the other six eggs hatched and were discarded. The period of gestation was 37 days and the incubation period was 59 days.

The writer expresses his appreciation to the following persons for helpful comments in preparing the manuscript: Roger Conant, James Cope, E. J. Koestner, Graham Netting, Niel Richmond, and G. T. Riegel.—JAMES A. MACMAHON, *Dayton Museum of Natural History, Dayton, Ohio.*

A LARGE SPINY SOFTSHELLED TURTLE.—What apparently is the largest spiny soft-shelled turtle, *Trionyx spinifer*, yet reported was added to the University of Minnesota's collections (No. 1494) recently. The specimen was taken July 23, 1956, in Swan Lake in Meeker County, Minnesota, by Mr. Paul Mertins of Waterville, Minnesota. Swan Lake connects with the Mississippi River through the Crow River system. Sometime later, the turtle was sold to Mr. Arthur Kurtz, a commercial turtle dealer in Minneapolis. He, in turn, reported the specimen to me and it was purchased from him for the University collection. The specimen measured 18 in. in carapace length, 13 in. in carapace width, and weighed 17 lbs. 6 oz. after at least 4 months without food.—W. J. BRECKENRIDGE, *Minnesota Museum of Natural History, University of Minnesota, Minneapolis.*

ANENT THE "DANGEROUS" BUSHMASTER.—My title is an allusion, without a parallel, to the paper by E. R. Dunn in 1925: "The 'harmless' coral snake." It may be mentioned that the locale of the Kipling story to which Dr. Dunn alludes is Uruguay, not Venezuela. The following account of the capture of a bushmaster for the small private zoo of my friend Raymond E. Stadelman, transmitted by him in a letter dated April 17, 1957, though unique in its subject, is so typical of snake stories in general that I wish to transmit it to my fellow readers of *COPEIA*. Mr. Stadelman is well known to older herpetologists from his early papers in the Bulletin of the Antivenin Institute of America, and from his curatorship of the serpentarium at Tela, Honduras, in the decade of the 1930ties. He has been stationed in recent years at the experimental rubber plantation at Villa Arteaga, Antioquia, Columbia, in the service of the Institute of Inter-American Affairs. Mr. Stadelman writes as follows:

"Just before I returned to Villa Arteaga Rubber Station on the 3rd of this month, two of the laborers brought in a large snake for me, which I now have in captivity. It is about 8 or 9 feet long, and the story of its capture is interesting, to say the least.

"One of the men was bathing with his wife at a nearby stream, when they saw this snake, and he told his wife that such a fine specimen would be very nice for the Stadelman collection. His wife was not enthusiastic, but he insisted that it was a harmless boa and he had seen me handle these. Between the two of them they managed to tie one of his shoestrings around the animals neck, and started to lead the snake to my house.

"The shoestring broke, since the snake did not want to go to my house, so the fellow retied the broken lace, and while he led the snake by the string, had his wife shoo and push it along from behind.

"In this manner they covered about half the distance to my house, when an Indian coming along and, somewhat popeyed at what he saw, told them: "Ay compadre, bushmaster very bad snake". The man's wife faded from the picture, and the man himself, with the help of another workman, got a good grip on the snake's neck and they brought it into the house. They say the poor fellow's knuckles were white and his hand and arm trembling with the force of his efforts by the time he got here. The bushmaster was in worse shape, and gasped for air for quite a while before it came around. It has long since recovered, of course, and behaves very much like the other, 8 foot, specimen I had—apparently a very sluggish snake.

"I have always had doubts about the famed aggressiveness of the bushmaster, and believe that this reputation is unwarranted. While I consider the

fer-de-lance to be very dangerous because it is nervous and apparently bites through fear, I think the bushmaster just doesn't give much of a damn about anything—it certainly does not seem to be afraid of people, but neither does it seem to dislike them. I have had this fellow out of the cage and in my hands, and, like the other one, he doesn't offer much resistance to handling, and when released, does not adopt a menacing attitude as would a fer-de-lance and many other species, for instance."

The non-aggressive behavior of the bushmaster recalls that of the equally inoffensive Gaboon viper. It seems well to know that *Lachesis mula* is not always aggressive, but one scarcely needs to be warned that a pit-viper with inch-long fangs is dangerous, whether aggressive or not, quite as one needs to be cautioned against the apparent harmlessness of coral snakes.—KARL P. SCHMIDT, *Curator of Zoology Emeritus, Chicago Natural History Museum, Chicago 5, Illinois.*

RANGE EXTENSION OF *LEPTODACTYLUS BUFONIUS*.—Recently I reported the presence of the chacoan batrachian *Leptodactylus bufonius* in the clayey soils of Jarilla, Alto Penasco and Balde in San Luis, central Argentina (1955, *COPEIA* (4): 291). The possibility was considered that this frog shares the underground social burrows of the rodents of the *Lagidium* group (vizcacheras) also found analogously in the true chacoan biocenosis. I can state now that some of the rodent communities observed in this xeric area are those of *Lagostomus maximus* (vizcacha pampeana); also there are many burrows of *Galea* (cuís) and *Microcavia* (Cavidae of the *Kerodon* group) as in the plains of La Rioja. The vegetation of the clayey ground between Jarilla and Balde shows some chacoan elements, and the ecological chacoan features are accentuated by the true *Lagostomus* communities and characteristic xerophilous flora. But the collecting station at Jarilla does not mark the western edge of the range of *Leptodactylus bufonius* at this latitude (33° 25' S.). On December 14, 1955, I found some subterranean nests and a few adult specimens of this species in a small area of clayey soil alongside the national road 8-9 miles west of the Desaguadero River, Mendoza Province. Thus, it is now apparent that *Leptodactylus bufonius*, once considered to be a chacoan species in Argentina (Vellard, 1948, *Acta. Zool. Lilloana*, 5: 171) actually occurs in the central xeric formations southward and westward along with the relict chacoan floristic biocenoses into the piedmont area of Mendoza.—JOSÉ M. CEI, *División Biología Animal, Departamento Investigaciones Científicas, Universidad Nacional de Cuyo, Mendoza, Argentina.*

RANGE EXTENSION OF *MACROCHELYS TEMNINCKI*.—On September 29, 1950, a commercial fisherman in Rock Island, Illinois, captured a 54-pound *Macrochelys temminckii* (Troost) in a frame trap. The locality was Rock Island County, Illinois in the Rock River at the mouth of a drainage ditch three miles east of a point where Illinois Route 150 crosses Rock River. The trap was in about four feet of water. The turtle was sold to a fish market in Muscatine, Iowa, where it was exhibited until it died. Harry G. Carl of Davenport, Iowa, recognized the turtle as an Alligator Snapping

Turtle, secured the carapace from the fish market, and retains it in his collection. The writer examined the carapace and snapshots of the live turtle and verified the identification of the turtle. There are five supramarginal laminae on each side between the first three laterals and the marginal series, together with three pronounced longitudinal ridges on the carapace. This range extension is at least one hundred and fifty miles north of that indicated by Archie Carr, *Handbook of Turtles*, 1952, Comstock, page 52.—ROBERT C. SCHRODER, 3424-32nd Street Court, Rock Island, Illinois.

## Ichthyological Notes

A NEW SPECIES OF EEL, *COLOCONGER MEADI*, AND NEW RECORDS FOR THE ATELEPID FISH, *IJIMAIA ANTELLARUM* HOWELL RIVERO, BOTH FROM THE GULF OF MEXICO.—Two specimens of *Coloconger*, from the Gulf of Mexico, were kindly loaned to me by Dr. Giles Mead, U. S. Fish and Wildlife Service. These specimens, identified as *C. raniceps* Alcock by Mead and Nicholson (1956, COPEIA (1): 62), represent a new species and the first record for this genus in the Atlantic Ocean.

Other genera of eels have been reported recently from the tropical western Atlantic and Gulf of Mexico, previously known only from the tropical Indo-Pacific fauna: Böhlke (1956, Proc. Acad. Nat. Sci. Philadelphia, 108: 66) recorded the first specimens of *Kaupichthys* from the Bahamas, and Ginsburg (1954, Jour. Washington Acad. Sci., 44: 256) described the first specimens of *Uroconger* from the Gulf of Mexico.

### CONGRIDAE

#### *Coloconger* Alcock

*Coloconger* Alcock, 1889, Ann. Mag. Nat. Hist., ser. 6, 4: 456, type species *Coloconger raniceps* Alcock.

A stubby eel with large eyes, short snout, cleft of mouth wide (extending beyond middle of eye), a single row of compressed teeth forming a sharply prominent serrated ridge in each jaw, teeth absent on vomer, vertical fins well developed and origin of dorsal fin above pectoral fins.

#### *Coloconger meadi* sp. nov.

Fig. 1A and B.

*Coloconger raniceps* (non Alcock) Mead and Nicholson, 1956, Copeia, (1): 62, pl. I.

HOLOTYPE.—USNM 157926, total length 291

mm., southwest of Dry Tortugas, Florida, 24° 16' north latitude, 83° 22' west longitude, captured in a 40 foot flat trawl at a depth of 375 fathoms, March 16, 1954 by Motor Vessel Oregon.

PARATYPE.—USNM 157927, total length 150 mm., data same as above.

Description.—Length of head 17.87 and 16.80 (first number for the holotype and the second for the paratype), tip of snout to origin of dorsal fin 22.00 and 18.27, tip of snout to anus 58.10 and 60.64, snout length 3.61 and 3.67, diameter of eye 4.81 and 4.86, all in percent of total length; origin of dorsal fin 46.50 and 25.90 per cent of length of pectoral fin behind base of pectoral fin; upper edge of gill opening about two-fifths of width of pectoral fin base above lower edge of pectoral base and in front of latter.

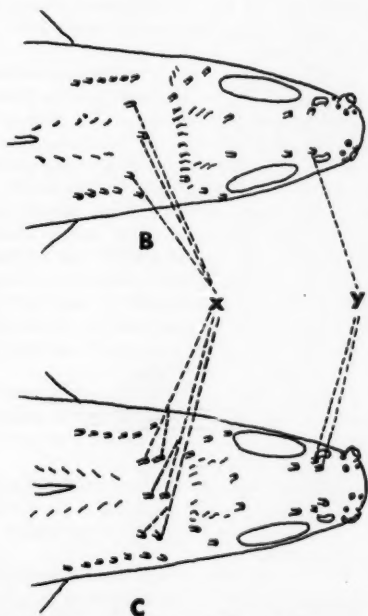
Pectoral rays 21 and 21; pores in lateral line (counted anteriorly from a vertical line through anus to a point on head where pores end) 72 and 71; supratemporal pores 3.

Body stubby with anus located in posterior half of total length; snout short and blunt, shorter than diameter of eye; posterior edge of eye about midway from tip of snout to upper edge of gill opening; cleft of mouth wide, extending beyond middle of eye; teeth in jaws compressed in a single row; vomerine teeth absent; premaxillary teeth compressed in 2 rows with a space between the rows; numerous sensory pores at end of short tubes on head and lateral line; a transverse row of sensory papillae on occiput and a row extending down posterior to eye, also 2 rows predorsally from origin of dorsal fin anteriorly, a row on each side of dorsal fin; lateral line extends along middle of body from head posteriorly to end of tail.

COLOR IN ALCOHOL.—Dusky pigment spots over the whole dark purplish body and fins in holotype;



A



C

Fig. 1. A, Lateral view of *Coloconger meadi* showing pores and sensory papillae. B, Dorsal view of *Coloconger meadi*; x, Supratemporal pores; y, Pores over posterior nostrils. C, Dorsal view of *Coloconger raniceps* from Indian Ocean.

in paratype body brownish in color; the sensory pores and papillae blackish.

REMARKS.—The species *C. meadi* is best distinguished from *C. raniceps* by the characters listed in the following key (see also Fig. 1). Named *meadi* for Dr. Giles Mead who kindly sent the specimens to me for examination.

# KEY TO THE SPECIES OF *Coloconger*

- 1a. Supra-temporal pores 3 (Fig. 1B); 1 pore present over posterior nostrils; head length 16.8 to 17.9 percent of total length. Gulf of Mexico  
*meadi* new species

- 1b. Supra-temporal pores 6 (in 3 pairs, Fig. 1C); 2 pores present over posterior nostrils; head length 20.5 percent of total length. Indian Ocean to Japan.....*raniceps* Alcock

## Ateleopidae

### *Ijimaia antillarum* Howell Rivero

*Ijimaia antillarum* Howell Rivero, 1935, Mem. Soc. Cubana Hist. Nat., 9 (2): 98, type locality Cuba, East of Havana; 1941, Mem. Soc. Cubana Hist. Nat., 15 (2): 173.

Six specimens of an ateleopid fish known from only two previous records were captured by the Motor Vessel *Oregon* in the Gulf of Mexico. Howell Rivero (1935; l. c.) described a new species, *Ijimaia antillarum*, which represents the first record of the family Ateleopidae from the western Atlantic. His specimen, 1636 mm. in total length, was found floating almost dead on the surface of the water several miles east of Havana, Cuba. In 1941 (l. c.), he recorded the second specimen, 1365 mm. in total length, collected near the first locality. On February 26, 1955, the Motor Vessel *Oregon* captured a third specimen USNM 157861, at station 1246, in a 40-foot flat trawl at a depth between 200 to 210 fathoms, south of Mobile County, Alabama, 29°15' N. Latitude, 88°18' W. Longitude. The following additional captures made by the *Oregon* are here recorded: USNM 157838, 4 specimens, station 1262, South of Mobile, Alabama, 29°10' N. Latitude, 88°03' W. Longitude, 80-foot balloon trawl, 250 fathoms, March 13, 1955; USNM 157993, 1 specimen, station 1567, 29°11' N. Latitude, 88°05' W. Longitude, 72-foot balloon trawl, 250 fathoms, June 23, 1956.

These specimens are characterized as *Ijimaia* in having a narrow pelvic girdle with a single median foramen and no ossified lamina. The counts and measurements for the 6 specimens are given below:

	USNM 157838				USNM 157861	USNM 157993
Standard length.....	539	592	643	537	713	304
Dorsal rays.....	9	9	10	10	10	9
Anal & caudal rays....	87	80	86	82	83	78
Pectoral rays.....	12	13	13	13	13	13
Pelvic rays (including rudimentary rays)	3	3	3	3	3	3
Gill rakers.....	1/9	1/9	1/9	1/9	1/9	1/9

—ROBERT H. KANAZAWA, U. S. National Museum, Washington, D. C.

AN ATLANTIC RECORD OF THE ZEOID FISH *PARAZEN PACIFICUS*—Three specimens of the zeoid species *Parazen pacificus* Kamohara, 1935 (Zool. Mag., 47: 245-247) were recently



caught by the United States Fish and Wildlife Service exploratory fishing vessel OREGON at the following two stations, both north of Caibarien, Cuba:

Station no. 1342. 23° 10' N. Lat., 79° 33' W. Long. 280 fathoms. 40-foot flat trawl. July, 1955. Two specimens.

Station no. 1343. 22° 59' N. Lat., 79° 17' W. Long. 250 fathoms. 40-foot flat trawl. July, 1955. One specimen.

Two of these fish were sent to the Chicago Natural History Museum and the third to the United States National Museum. A fourth specimen, collected by Dr. Kiyomatsu Matsubara off Japan near Kamohara's type locality, is in the collection of the Natural History Museum, Stanford University. Through the courtesy of the curators of these institutions I have been able to compare these four specimens.

The Japanese fish differs slightly from those from the Atlantic in the number of dorsal and pectoral rays, the deeper body, the longer caudal fin and the placement of the ventral fins. These populations are probably specifically or subspecifically distinct, but since I lack the material necessary to define them adequately I have referred both to *Parazen pacificus*.

Since Kamohara's type series did not include Atlantic material and his description (largely in Japanese) omitted several characteristics which subsequent ichthyologists have used in the classification of the zeoids, I include here a diagnosis of *Parazen* and its single known species, *P. pacificus*.

*Parazen* Kamohara, 1935

Gills  $3\frac{1}{2}$ , with no slit behind the last. Pseudo-branchiae present. Seven branchiostegal rays. Suborbital shelf poorly developed. Occipital crest long and thin. Anterior dorsal trunk muscles terminating anteriorly on the posterior crest of the frontal bones. Scales moderate in size, deciduous, and weakly ctenoid. 34 (33+1) vertebrae. Caudal fin forked, with 11 (I-9-I) principal rays. Ventral fins thoracic, without a true spine and composed of one unbranched and six branched rays.

*Parazen pacificus* Kamohara, 1935

(Plate I, Table I)

Dorsal fin divided; VIII,  $26\frac{1}{2}$  to VIII, 30. Anal fin I-31 $\frac{1}{2}$ , the spine small. Pectoral fin 15 (in the Japanese specimens) or 16 (in the Atlantic). Seven branchiostegal rays. About 90 scales in a mid-lateral series. 1+6 or 2+6 gill rakers on first arch, exclusive of rudiments.

Body compressed and more elongated than most other zeoid species. Back and belly equally rounded. The greatest depth of body, at the origin of the spinous dorsal fin, 2.1-2.9 in standard length; the

greatest width of body 6.4-7.7 in standard length. Caudal peduncle moderately stout, its least depth 8.2-9.0 in standard length.

Snout pointed; the lower jaw terminal when the premaxillary is retracted. Premaxillaries extremely protractile; the posterior process is received by a broad space between the frontal bones. These processes, when retracted, extend to a point above the center of the eye and nearly to the posterior crests of the frontal bones. Mouth large, the maxillary and premaxillary terminating below the anterior edge of the eye. Both bones compressed and vertically expanded posteriorly. Premaxillary length 4.7-5.0 in standard length. Eye moderate in size, slightly elliptical, the vertical diameter shorter than the horizontal; the horizontal diameter 2.8-5.2 in length of head.

Teeth present on the mandible, premaxillaries and vomer. None on the slender palatine bones or on the narrow pointed tongue. The rami of the mandible bear a single row of slender, conical, pointed teeth. There is a patch of similar teeth on the symphysis. The premaxillaries bear double rows of shorter teeth posteriorly which become single rows further forward. Since the anterior ends of the premaxillaries are not ankylose but are loosely joined by the overlying skin and separated by fascia, there is no patch of premaxillary teeth which corresponds to the symphyseal patch of the mandible. Each side of the vomer bears about four short but strong teeth.

There are 1+6 or 2+6 short and flattened gill rakers on the first arch and one or two additional rudiments on each limb. Each raker bears a row of spines along its distal edge.

Most external head bones have smooth edges and surfaces. Some parts of the edges of the opercular bones and the supraorbital frontal ridges are weakly serrated.

The two lateral lines, one originating immediately above, the other below, the junction of the gill flap with the body wall, diverge and then follow a nearly parallel course, about four scale rows apart, to a point below the origin of the soft dorsal fin. There is an oblique lateral line segment joining these two lines. Beyond the level of the spinous dorsal these lines converge; they become united at a point beyond the end of the soft dorsal fin. No lateral body scales remain on any of the four specimens, but the scale pockets overlying the two lower lateral lines differ from the remainder in size and shape. The single posterior lateral line can be traced to the base of the midcaudal rays, and a few lateral line scales remain on the base of the caudal fin. The last of these, a triangular pointed scale longer than its predecessors, extends over the bases of the central caudal rays beyond the scaly sheath which adorns the base of the caudal fin. A third indistinct line



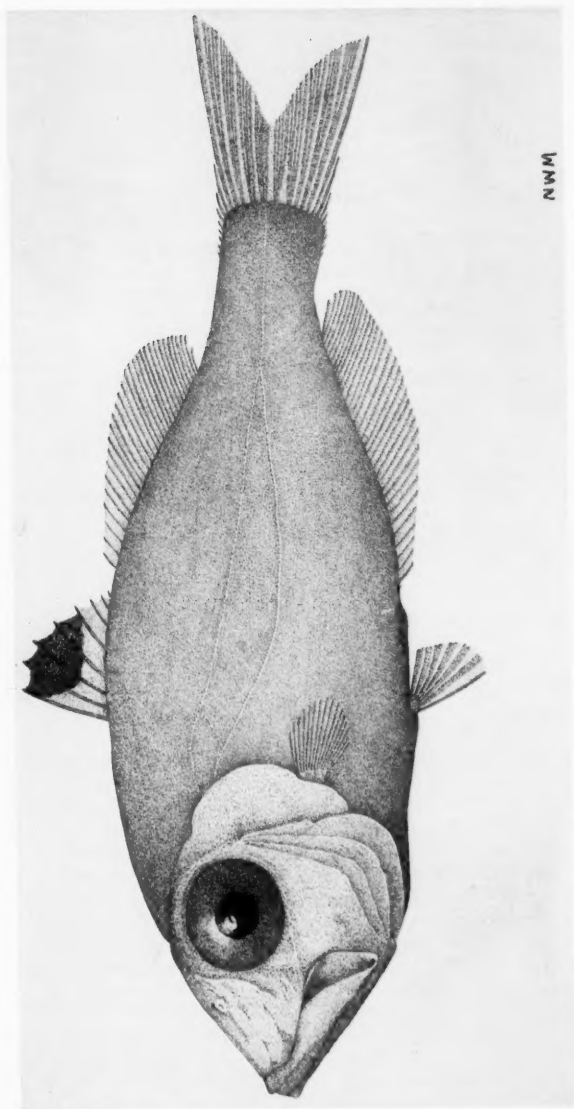


Plate I. *Parazen pacificus*. From Oregon station number 1343. U. S. National Museum number US157874. Drawn by Nancy W. Mead.

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TABLE I  
MEASUREMENTS (IN MILLIMETERS AND IN PERCENT OF STANDARD LENGTH) AND COUNTS OF THREE SPECIMENS  
OF *Parazen pacificus*.

	Oregon station No. 1343 (USNM 157874)		Oregon station No. 1342 (CNHM)		Off Shikoku, Japan (SU 32255)	
	mm.	% S. L.	mm.	% S. L.	mm.	% S. L.
Standard length.....	94.0	100	96.5	100	118.0	100
Fork length.....	106.0	112.8	106.5	110.3	134.5	114.0
Length of head.....	35.0	37.2	38.0	39.4	45.0	38.1
Greatest depth of body.....	33.5	35.6	33.0	34.2	46.5	39.4
Least depth of caudal peduncle.....	11.5	12.2	11.5	11.9	13.0	11.0
Greatest width of body.....	13.0	13.8	15.0	15.5	15.5	13.1
Length of snout.....	14.0	14.9	14.5	15.0	19.0	16.1
Horizontal diameter of eye.....	12.5	13.3	12.0	12.4	14.5	12.3
Width of interorbital.....	10.0	10.6	10.0	10.4	11.5	9.7
Length of premaxillary.....	19.0	20.2	20.5	21.2	24.0	20.3
Length of premaxillary process.....	19.5	20.7	21.0	21.8	24.5	20.8
Length of pectoral fin.....	9.0	9.6	10.0	10.4	12.5	10.6
Length of ventral fin.....	10.5	11.2	12.5	13.0	14.5	12.3
Length of mid-caudal ray.....	12.0	12.8	10.0	10.4	16.5	14.0
Length of longest dorsal spine.....	11.5	12.2	—	—	12.0	10.2
Length of longest dorsal ray.....	10.0	10.6	11.5	11.9	12.0	10.2
Length of longest anal ray.....	11.0	11.7	11.5	11.9	12.5	10.6
Distance from snout to origin of dorsal fin.....	43.5	46.3	—	—	56.0	47.5
Distance from snout to origin of anal fin.....	56.5	60.1	56.0	58.0	73.5	62.3
Distance from snout to origin of ventral fin.....	44.0	46.8	46.0	47.7	60.0	50.8
Length of base of anal fin.....	29.0	30.9	30.0	31.1	36.5	30.9
Length of base of spinous dorsal fin.....	13.5	14.4	—	—	18.0	15.3
Length of base of soft dorsal fin.....	24.5	26.1	—	—	31.0	26.3
Distance from origin of dorsal fin to origin of anal fin.....	35.0	37.2	—	—	47.0	39.8
Counts:						
Dorsal fin.....	VIII, 30		—		VIII, 27 ½	
Anal fin.....	I-32½		I-32		I-32 ½	
Caudal fin.....	I-9-I		I-9-I		I-9-I	
Pectoral fin.....	16/16		16/16		15/15	
Ventral fin.....	7/7		7/7		7/7	
Gill rakers (incl. rudiments).....	1+8		2+8		2+9	
Gill rakers (excl. rudiments).....	1+6		2+6		1+6	

is visible in two of our specimens which may represent a part of the lateral line system. The nature of the scale pockets overlying this line suggests that it lacks the modified scales which are characteristic of the lower two lateral lines. This upper line rises nearly vertically from its origin near the upper end of the gill opening, arches along the back of the fish, and terminates below the soft dorsal fin.

Scales present on the cheek below the eye, but absent from the snout, jaws, opercular region, and nape anterior to the frontal crests. Scale pockets present on body but most of the scales of all four available specimens have been lost. The few remaining are weakly ctenoid. The bases of the dorsal, anal, and caudal fins are covered by a fleshy, scale-bearing sheath. No enlarged keeled plates along the dorsal or ventral midlines, and the bony, spine-bearing protuberances frequently seen along the dorsal and anal bases of many zeoids are greatly reduced. The bony ridges on each side of the dorsal and anal fins bear small protuberances which correspond in number and position to the rays of these

fins. The development of these ridges resembles that of *Cyttopsis*.

All fins are of moderate length and strength. The spinous dorsal fin is completely separate from the soft dorsal and the dorsal spines are slender. The caudal fin is forked. The principal rays are flanked above and below by about eight procurent caudal rays. The pectorals are short and rounded, with no divided rays. There are seven rays in the ventral fin, the first simple, the others branched.

One of the four specimens is too badly damaged to provide morphometric data. The measurements and counts taken from the remaining three are recorded in table one.

This species is now known from below 80 fathoms off Shikoku, Japan, and from depths of 250 and 280 fathoms in the Atlantic off northern Cuba.—GILES W. MEAD. *U. S. Fish and Wildlife Service, U. S. National Museum, Washington, D. C.*

THE OCCURRENCE OF THE DEEP-SEA ANGLERFISH, *CRYPTOPSARAS COUESII*,

IN MONTEREY BAY, CALIFORNIA.—On September 11, 1956, the trawler, THREE SISTERS, made a haul in about 80 fathoms some eight miles south southwest of Santa Cruz, California (36°49' N. Lat., 122°00' W. Long.), and in the catch Captain Dominic Passanisi found a large female of the deep-sea anglerfish, *Cryptopsaras couesii* Gill, with two parasitic males attached. This specimen he kindly gave to the Hopkins Marine Station for study.

This capture is notable in a number of respects. It is the first known record of *C. couesii* on the Pacific Coast of America north of the Bay of Panama and extends the range 28° of latitude. Previously there were only two species of ceratioids known from California, *Oneirodes acanthias* (Gilbert) and *Microlophichthys microlophus* (Regan), both of the family Oneirodidae. Thus the family Ceratiidae is added to the ichthyofauna of California. Another interesting feature of this specimen is the presence of the two parasitic males attached to the belly. The only other parasitic male reported for this species was described by Barbour (1941 Proc. New England Zool. Club, 19: 7-14) from a specimen taken by Tanaka in 1908. Judging from Barbour's figure, the Japanese male was either extremely degenerate or severely damaged. The two specimens attached to this female are, on the other hand, in excellent condition. Finally, this is the sixth specimen of 100 mm. or larger to be reported, and its standard length of 213 mm. (345 mm. total length) probably makes it the second largest specimen known. The largest

individual taken is Tanaka's specimen measuring 290 mm. standard length (440 mm. total length). Bertelsen (1951: Dana-Report No. 39: 141), in presenting his list of large specimens, gives the total length of this specimen, and it is presumed that the value of 300 mm. given for Saemundsen's specimen, in the same list, is also for total length. Saemundsen's paper is not available to me.

This specimen was taken in a commercial haul and the heavy weight of the accompanying market fishes caused a mass of eggs to be forced from the genital opening where they remained attached. A random sample of 100 of these was measured; the egg diameters varied from 0.06 to 0.49 mm. The size distribution showed a sharp mode at 0.40 mm. and a lesser mode at 0.26 mm. The fact that 51 of the ova were between 0.37 and 0.49 mm. in diameter might indicate that the specimen was near spawning; and since 46 of these eggs varied in diameter from 0.06 to 0.30 mm., this species may have more than one spawning a year. This possibility is supported somewhat by Bertelsen's discussion (1951, op. cit.: 198-207), in which he shows that the larvae of *C. couesii* are present in the Atlantic during most months of the year, with the greatest numbers occurring during the summer.

A considerable amount of evidence is presented by Bertelsen (1951, op. cit.: Figs. 127, 130; Tables 46a, 46b, 47, 48) indicating that *C. couesii* is an inhabitant of water warmer than that which normally characterizes Monterey Bay. In this connection, it is interesting to note that during the late summer of

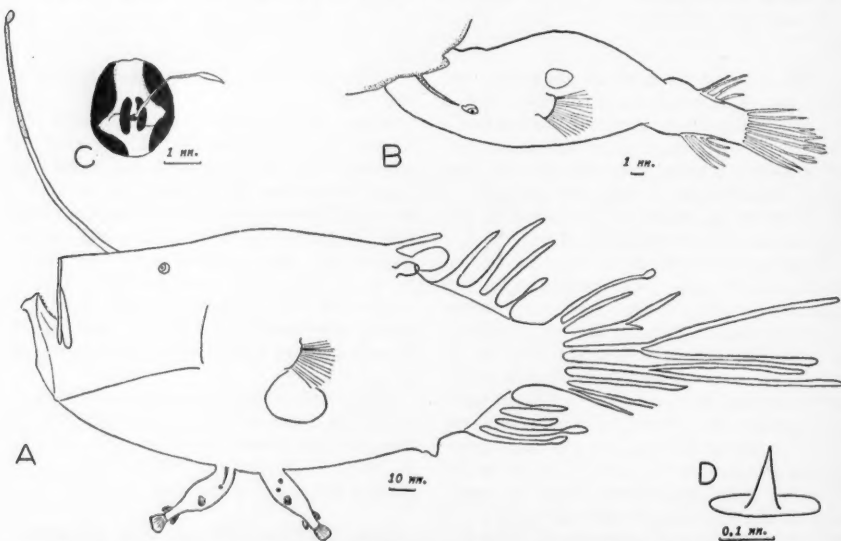


Fig. 1. A. Outline drawing of a large female *Cryptopsaras couesii* with two parasitic males. B. Parasitic male. C. Detail of the esca. D. "Thumbtack" scale from the female specimen.

1956 the surface waters of the bay were warmer than in any of the five preceding years. Monthly averages for September, based on weekly observations in the mouth of Monterey Bay (approximately 36°42' N. Lat., 122°02' W. Long.), ranged from 12.65° to 13.84° C. during the period 1951-1955. In 1956, it was 14.42° C., or 0.58° higher than in the warmest of the five preceding years (1951). Skogsberg (1936, Trans. Amer. Philos. Soc., 29: 129-133) has presented good evidence to support his contention that the warm water which enters the bay in either late summer or early fall is derived from the California Current. While this southward-moving water is a cold current for this latitude, it has a higher temperature than is usually found in the upwelled coastal waters of the preceding months. Since this current is not a strong one, but rather a sluggish meandering flow of North Pacific water, its course varies from year to year. In some years, it is far at sea, and in others it impinges directly on the shore. Its seaward location is most easily indicated by the distance to sea which commercial trollers must travel to catch the albacore, *Germo alalunga*. The year 1956 was a good year for the fishermen; they were able to make successful catches well within the sight of land, and albacore were taken as far north as the mouth of the Columbia River. Other warm-water fishes, the bluefin tuna (*Thunnus saliens*), the yellowfin tuna (*Neothunnus macropterus*), and the bonito (*Sarda lineolata*), were taken within the confines of Monterey Bay during this period (J. B. Phillips, personal communication). These fishes are assumed to migrate northward on the warmer tongues of the California Current and may be used as indicators for the location of the current in relation to the coastline. The facts indicate that the current entered Monterey Bay during the summer of 1956, bringing its associated organisms. Since *C. couesii* has only weak swimming powers (Bertelsen, op. cit.: 238) and is more planktonic than nectonic, it is probable that this specimen was an inhabitant of the far open Pacific which had strayed into the periphery of the eastern North Pacific gyre and was carried into the shallow waters near Santa Cruz by a particularly strong coastal invasion of this water mass. Thus, it might be more accurate to state that this is an eastern rather than a northern extension of range. A northern coastwise migration from the Panamanian region to the California coast would require the fish to swim against prevailing currents of considerable force, a feat that seems to be far beyond its power.

Except for being badly skinned and having the basal bone pulled anteriorly beyond its normal position, the female is in good condition. It is deemed advisable to present the following descriptions; the synonymy is not included because of Bertelsen's adequate treatment (op. cit.: 139).

TABLE I  
COUNTS AND MEASUREMENTS OF THREE SPECIMENS  
Measurements expressed as per thousandth of standard length

Character	♀	♂	♂
Standard length in mm.....	213.0	27.6	27.1
Total length.....	1620	1323	1338
Length of head.....	478	482	512
Length of snout.....	185	254	211
Length of maxillary.....	178	—	—
Body depth at vertical of pectoral fin.....	451	301	321
Depth of caudal peduncle.....	108	90	93
Origin of dorsal fin.....	761	831	873
anal fin.....	854	866	876
Base of dorsal fin.....	136	81	89
anal fin.....	98	69	73
Longest ray second dorsal.....	198	—	—
second anal.....	195	—	—
fourth caudal.....	662	283	320
Number of dorsal rays.....	4	4	4
anal rays.....	4	4	4
caudal rays.....	2+4+2	2+4+2	2+4+2
pectoral rays.....	15	ca. 15	ca. 15
branchiostegal rays.....	6	—	—

FEMALE:—Head large. Occipital region flat transversely, the interorbital space becoming progressively concave anteriorly; dorsal profile of head gently rounded. Snout almost horizontal, straight, and a direct continuation of the dorsal profile. Mouth vertical. Maxillary extending down to the level of the pectoral. Between the median heads of the premaxillary bones, there is a large area of soft gelatinous tissue from which the skin had been torn; this tissue has the appearance of a luminous organ. A large symphyseal knob on the lower jaw about equal to the diameter of the eye. All teeth depressible. Premaxillary with a narrow band of two or three rows of very small teeth. Each dentary with about 18 teeth irregularly placed in two rows. The largest of the median teeth about equal to the diameter of the pupil, reduced in size toward the angle of the jaw. Vomer with three teeth on the right and four on the left. Tongue large and smooth, almost filling the oral cavity. Gills 2½. Gill rakers reduced to small irregular protuberances. Operculum fleshy; gill opening tube-like, its diameter about equal to the depth of the caudal peduncle; an ovoid area of lighter-pigmented skin at the gill opening, extending to the vertical of the tip of the pectoral, its longest measurement 0.7 maxillary length. Eye small, about 0.05 head. Nostrils not found. The basal bone, or "fishing pole," is about equal to the standard length; it extends from a groove formed by the concave median edges of the

frontal bones. In Figure 1 (A) the stippled area indicates the amount of skin which remained on the basal bone of this specimen. Illicium, the flexible stalk carrying the luminous lure, short, less than the diameter of the esca. Esca, the luminous lure, about equal to the diameter of the eye and possessing a characteristic H-shaped pattern of dark pigment in the center of the luminous tissue (Fig. 1, C); filament simple, short, equal to about two diameters of the esca. Second cephalic ray not found.

Body deepest at the vertical of the base of the pectoral fin; tapering acutely to the caudal peduncle. Width of body about equal to the depth of the caudal peduncle. Anus about 0.6 depth of the caudal peduncle in advance of the anal fin. Pectoral pedunculate. The two upper and two lower caudal rays are simple, the uppermost ray with a swelling on its tip. The tips of the other simple rays were lost and show no evidence of such terminal enlargements. The remaining caudal rays are forked, the two central ones for about 0.6 of their length and are tentacle-like without bony support for the greater part of their length.

The three caruncles, club-shaped luminous glands, lie anterior to the dorsal fin in a transverse row across the back. The lateral caruncles have a clear area of lens-like tissue at their tips; the central one, about three times larger than the laterals, lacks this clear area. These glands secrete a slime which contains luminous granules (Bertelsen, op. cit.: 239). Even after preservation, squeezing these glands will force out the secretion. On the midline just anterior to the dorsal caruncles lies the dorsal tentacle, which acts as a sheath for the basal bone. In this specimen, the basal bone is completely pulled from the dorsal tentacle which here has a length almost equal to that of the anal base.

The body is jet black and covered by minute "thumbtack" spines that are deeply imbedded in the skin with only the tips showing (Fig. 1, D). These spines are approximately one-half as tall as the diameter of the base which is about 0.2 mm. The base is concave, and the spine is hollow for about one-half its length.

**PARASITIC MALE:**—The male does not possess any visible basal bone or luminous structures, and body proportions vary from those of the female.

Head long, both sides of the head not necessarily equal. This inequality is due to the position of attachment. Occiput convex. Dorsal profile of the head gently rounded. The profile of the snout differs in the two specimens at hand; that of the anterior male is acutely rounded (Fig. 1, B), while the posterior specimen has a gently rounded snout. The lips are not completely fused together; however, with aid of a fine pipette, it was not possible to force air through the mouth and out past the operculum, indicating that the mass of female tissue which is taken into

the mouth for attachment not only blocks off the alimentary canal but also the path of the respiratory current. Nostrils not seen. Eye small, less than equal to the base of the pectoral. Body deepest at the vertical of the pectoral fins; tapering gently to swellings just anterior to the dorsal and anal fins, where the depth is 0.12 standard length. Anus at 1.4 depth of caudal peduncle in advance of the anal base. Pectoral pedunculate.

Both males of the Monterey Bay specimen are jet black of the same intensity as the female; not lighter as was illustrated for the Japanese specimen (Tanaka, 1908, Jour. College of Sci., Imperial Univ. of Tokyo: Pl. II, Fig. 3).—THOMAS N. FAST, Hopkins Marine Station, Pacific Grove, California.

**FISH RECORDS FROM LONG ISLAND SOUND.**—During the summer and fall of 1956 three species of fishes were brought to our attention because of their rarity in Long Island Sound and the consequent high degree of interest occasioned by their capture.

*Salmo salar salar* Linnaeus. An Atlantic salmon was taken on June 20, 1956 in a trap on the west side of Black Point near the mouth of the Niantic River. The scales indicated two years of fresh water life and more than two years in the sea. This female specimen weighed 10 pounds 1 ounce and was 744 mm. in fork length. The length and weight are but slightly less than the averages given by Kendall (1935, Mem. Boston Soc. Nat. Hist., 9 (1): 60) for 13 specimens with the same type of life history from Casco Bay, Maine. Salmon are extremely rare in Connecticut waters. Merriman and Jean (1949, Copeia, (3): 220–221) reported a specimen taken by seining in the Connecticut River on June 10, 1948, the first published record in the twentieth century. They suggested that because of the heavy snows of the previous winter, and the wet spring, greater than usual run-off might have made the river "more attractive to a stray individual at the southern end of its range than in other years." It may be significant that similar weather conditions prevailed in 1956. Mr. Edward Proctor, operator of the trap in which the present specimen was found, reported that during the war years he had taken two salmon weighing 13 and 17 pounds. He added that in his forty odd years of operating fish traps in the area he had found only these three salmon. A mount of the latest specimen is in possession of the Director of the Connecticut State Board of Fisheries and Game.

*Anarhichas lupus* Linnaeus. A female wolfish, total length 800 mm. and weight 4.7 kg., was taken on May 17, 1956 in an otter trawl by the boat "Two Brothers" 1½ miles south of Falkner Island in Long Island Sound. The fish behaved in a vicious manner, snapping with accuracy and vigor at anything moving near it. Examination of a single



otolith indicated an age of five to seven years. The specimen bears Bingham Oceanographic Collection number 3736. The wolffish is definitely a cold water species, although in times past it apparently ranged as far south as New Jersey. At present, Nantucket Shoals seems to be the southerly limit, and Bigelow and Schroeder (1953, Fish. Bull. U. S. Fish Wildlife Serv., 53: 506) state: "We have heard of none caught to the westward and southward of Vineyard Sound at any time during the past half century." There is no definite record of a previous capture in Long Island Sound. Linsley (1844, Amer. Jour. Sci., 47: 65) included it in his list of Connecticut fishes, but with a query, for he had no specimens.

*Pseudopriacanthus altus* (Gill). A short big-eye, 38 mm. standard length, BOC number 3738, an invader from the south Atlantic, was taken on October 8, 1956 in an oyster dredge of the Mansfield Oyster Co., operating just outside the middle breakwater of New Haven harbor. This species strays as far north as Massachusetts, and is therefore expected to reach Long Island Sound, but there is only one previous record (Breder and Nigrelli, 1934, Copeia, (4): 195) in this almost-enclosed body of water.—JAMES E. MORROW, *Bingham Oceanographic Laboratory, Yale University, New Haven, Connecticut.*

**ADRENAL CORTICAL HORMONES AND OSMOTIC STRESS IN THREE SPECIES OF FISHES.**—Since the role of the adrenal cortex in regulating salt and water balance in mammals is known, the author considered it desirable to explore the possible influence of certain adrenal cortical preparations on osmoregulation in teleosts. Previous work in this area was done on elasmobranchs (see "Hormones in Fish" in the review by W. S. Hoar, Publ. Ont. Fish. Res. Lab., 1951) but no reference to work on the teleostean fishes was found. (Adrenalectomy is not possible as a method of approach to this problem in teleosts for anatomical reasons.)

Three species, taken from habitats differing in salinity, were used in the following experiments. The strictly marine clingfish, *Gobiesox maeandricus*, was obtained at South Bay, Cape Arago, Oregon. Specimens were collected of the northern staghorn sculpin, *Leptocottus armatus armatus*, near the fish docks at Charleston, Oregon; they were living under estuarine conditions though the species itself is primarily marine. The freshwater fish was the common goldfish, *Carassius auratus*, of the comet variety.

The fishes were kept in divided ten-gallon tanks partially immersed in a refrigeration bath so that the water was constant at 10° C. Aeration was continuously supplied. The seawater and various dilutions were not circulated, but used in a static system with occasional replacement.

After acclimation to laboratory conditions the

marine fishes in each hormone-injected group and controls were subjected to the following diluted seawater series (osmotic stress pattern):

Salinity	Time in Days
‰	
25.5	2
16.6	2
7.5	8
3.3	1
fresh water	7 hrs.

The goldfish were kept at salinities of 7.5 ‰ and 16.6 ‰ for 2 and 1 day respectively.

In all series injections were made at the time of each transfer to the next higher or lower dilution series. Two injections were made during the 8-day period at 7.5 ‰ salinity, the second two days after transfer. The range in weights of the fish were as follows: *Gobiesox*, 32.5 gms. to 12.8 gms.; *Leptocottus*, 29.5 gms. to 11.1 gms.; *Carassius*, 11.5 gms. to 4.9 gms.

Hormones used were:

1. ACTH. Obtained from Armour Research Division Porcine Origin Lot No. 84-5HS1. This was triturated, 50 mgm with 1 cc of 1 N HCl; brought up to 5 cc. with 100 mM Huf's 0.4 Ringer Solution. All other dilutions were made by withdrawing 1 cc and making serial dilutions using Huf's 0.4 Ringer. The solutions were pH 6 and were stored prior to use at 2° C.

2. Adrenal Cortex Extract. Obtained from Parke, Davis and Co., "Eschatin" (Suprarenal Cortex Extract). Solution from the bottle was 50 dog units per cc. Dilutions were made with Huf's Ringer.

The ACTH was administered in concentrations of 1/10, 1/100, 1/1000, 1/10,000 each in 1/10 cc amounts to four separate groups of each species, 5 fish to a group. Controls were fish injected with 1/10 cc of isotonic saline as well as non-injected fish.

Adrenal Cortex Extract was given in concentrations of 1 dog unit, 1/10, 1/100, 1/1000 dog units in the same manner as above. Injections were made into the abdominal cavity. A No. 27 needle was used with a ½ cc tuberculin type syringe.

The goldfish were given ACTH in one dosage only (1/10 mgm in 1/10 cc) and Adrenal Cortex Extract in one dosage only (1/10 dog unit in 1/10 cc.)

The following observations were made:

1. There was no significant difference in terms of survival of the clingfish and of the sculpins injected with ACTH and Adrenal Cortex Extract when compared to their controls (Table I). No real trend is evident; variations in survival must be caused by inherent variability of the fish in tolerating the osmotic stress and experimental techniques to which they were subjected. When the salinity of their

TABLE I  
SURVIVAL OF *Leptocottus armatus*, *Gobiosox maeandricus* AND *Carassius auratus* UNDER OSMOTIC STRESS, AS INFLUENCED BY INJECTIONS OF ACE AND ACTH  
For osmotic stress pattern, see text

Injections	Range and mean survival in days		
	<i>Leptocottus</i>	<i>Gobiosox</i>	<i>Carassius</i>
None.....	(5-11) 7.2	(13.3) 13.3	
Saline.....	(6-13) 7.6	(13.3) 13.3	(2.8) 2.8
ACE			
10 <sup>-3</sup> dog units.....	(1-6) 4.6	(13.3) 13.3	
10 <sup>-2</sup> dog units.....	(1-13) 8.2	(13.3) 13.3	
10 <sup>-1</sup> dog units.....	(6-7) 6.4	(13.3) 13.3	(2.8) 2.8
1 dog unit.....	(1-11) 6.6	(13.3) 13.3	
ACTH			
10 <sup>-4</sup> mg.....	(5-11) 6.8	(13.3) 13.3	
10 <sup>-3</sup> mg.....	(1-11) 7.0	(13.3) 13.3	
10 <sup>-2</sup> mg.....	(6-11) 7.4	(7-13.3) 12.0	
10 <sup>-1</sup> mg.....	(5-13) 8.2	(13.3) 13.3	(2.8) 2.8

environment was progressively lowered the sculpins in most cases died in 7.5 ‰ salinity and all the clingfish expired after seven hours in fresh water with one exception.

2. When subjected to a progressive rise in the salinity of their environment all goldfish had died after 20 hours in a salinity of 16.6 ‰. There was no difference between the two experimental groups and the control group (Table I).

From this limited study it appears that ACTH and Adrenal Cortex Extract have no significant influence on the tolerance limits to osmotic change in the strictly marine *Gobiosox maeandricus*, the marine estuarine *Leptocottus armatus armatus*, and a freshwater fish, *Carassius auratus*.

This preliminary work was carried out under Contract Nonr 692(00) for research in adrenal physiology between the University of Oregon and the Office of Naval Research. The contract was headed by Dr. Bradley T. Scheer. The writer wishes to acknowledge the technical assistance of Mr. J. D. Kreuger.—ARTHUR S. LOCKLEY, *Zoology Department, Long Beach State College, Long Beach 15, California.*

DISTRIBUTIONAL RECORDS OF FISHES FROM WATERS OFF NEW ENGLAND AND THE MIDDLE ATLANTIC STATES.—The data recorded here concern either species which are new to or have seldom been recorded from certain areas, or distributional information which has bearing upon the life histories of species. In addition to our personal observations, sources of records, for which we are greatly appreciative, include Captain Norman Benson, Mr. L. R. Day, of the Fisheries Research Board of Canada, and members of the

crews and scientific parties of the research vessels ATLANTIS, BEAR, BLUE DOLPHIN, and CARYN of the Woods Hole Oceanographic Institution.

*Hypoprius signatus*. Night Shark. Taken, probably at the surface, from the R/V ATLANTIS, October 16, 1953, at 38°22'N, 69°35'W. Bigelow and Schroeder (1948, *Fishes of the Western North Atlantic I*: 316-319) record this species from off South Carolina (33°37'N, 77°36'30'W), previously the northernmost record.

*Elops saurus*. Ten Pounder. Four specimens, 29.3-31.8 cm. fork length, were taken in Benson's trap net at Quisset, Massachusetts (Buzzards Bay) on October 18, 1955. While this species is occasional near Long Island and southern Cape Cod, most are seen before October.

*Sphyræna borealis*. Northern Barracuda. A specimen, 21 cm. fork length, was taken by Norman Benson in James Pond, Martha's Vineyard, on October 30, 1955. This is in keeping with previous accounts (cf. Nichols and Breder, 1934, *Zoologica* 9: 1-92) that the species is most often seen after October 1. Since young are more frequently taken than adults, in northern waters, the present specimen is noteworthy.

*Katsuwonus pelamis*. Oceanic Bonito. L. R. Day reports one specimen 43.5 cm. fork length, taken in a drift gill net at 41°06'N, 64°12'W, on July 19 or 20, 1955, and another was caught from the R/V BEAR on September 18, 1956 at 40°40'N, 68°28'W. Nichols and Breder (1934, *loc. cit.*) state that this species is irregular in the New York-New England area, but numerous offshore. There are few published records for the western Atlantic off northern North America, but it is frequently taken in the summer by sport fishermen in Middle Atlantic and southern New England waters. It is more common in tropical waters. Another record of this species from a fish trap near Provincetown, Massachusetts, in the summer of 1954 is the second Gulf of Maine specimen (the first since 1880; cf. Bigelow and Schroeder, 1953, *Fishes of the Gulf of Maine*).

*Thunnus albacares*. Yellowfin Tuna. Two specimens taken on trolled lines from the R/V ATLANTIS: one, 66.1 cm. fork length, on August 19, 1953 at 37°22'N, 71°05'W, the other 113.4 cm. fork length on September 29, 1954 at 37°02'N, 67°34'W; and one, 58.0 cm. fork length, from the R/V CARYN on August 9, 1949 at 38°21'N, 71°37'W. These records, together with those of Mather, 1954 (*Copeia* (4): 292), seem to indicate a fairly regular occurrence of yellowfins during the fall (August to November) not far off the continental shelf south of New England. Perhaps long-line fishing would establish the presence of a relatively regular seasonal population at greater depths than are normally fished.

*Thunnus alalunga*. Albacore. A specimen 81 cm.

in fork length was caught by trolling from the R/V BEAR, September 12, 1956 at 39°45'N, 73°00'W and preserved by R. H. Backus. While this species may not be uncommon in the western North Atlantic, most reports of it have not been substantiated by specimens. Bullis and Mather (1956, Amer. Mus. Novitates 1765: 1-12) give data on Caribbean specimens, and Mowbray (1956, Proc. Gulf and Carib. Fish. Inst. 8th Ann. Sess. 1955: 138) reports the capture of specimens by means of a long-line near Bermuda. The specimen reported here is the northernmost substantiated record in the western North Atlantic.

*Auxis thazard*. Frigate Mackerel. Cape Cod has commonly been considered the northern limit for this species. A specimen about 33 cm. fork length from a fish trap at Barnstable, Massachusetts on August 1, 1954 may represent a most northerly record, and is the first record for the Gulf of Maine. Several offshore records from near the supposed northern limit include the following: six specimens from 40°58'N, 64°06'W, and 15 specimens from 41°06'N, 64°12'W, sizes ranging from 29.5-32.5 cm. fork length, taken with drift gill nets from July 12-20, 1955, reported by L. R. Day; one, 34.6 cm. from the M/V BLUE DOLPHIN, June 29, 1953, at 40°05'N, 70°05'W. Mather has caught four specimens near No Man's Land off Martha's Vineyard in late July and early August 1954 and 1955, although he had never taken one in extensive fishing in this area in the years 1947-1953.

*Sarda sarda*. Common Bonito. Mr. J. Israel Pothier of the Wedgeport Tuna Guides Association showed us a specimen of this species, taken in a herring net off Shag Harbour (Lobster Bay), Nova Scotia on September 10, 1956, and brought to him by Captain John Jacquard. Bigelow and Schroeder (1953, *op. cit.*) report the species as uncommon in the northern Gulf of Maine, but note that young have been taken at Halifax. The present specimen was an adult, approximately 13 inches long.

*Scomberomorus cavalla*. King Mackerel. Nine specimens were noted in 1955 from Benson's trap in Buzzards Bay, Massachusetts, two on September 14, four on October 3 and three on October 18. These were all about the same size, two measured fish being 23½ inches and 27½ inches fork length. There is a record of this species from North Truro, Massachusetts, in the Gulf of Maine (Bigelow and Schroeder, 1953, *Op. cit.*: 349). Generally speaking, however, the northern limit of its range appears to be the south side of Cape Cod, from which it has been reported in the past (cf. Sumner, *et al.*, 1913, Bull. U. S. Bur. Fish. 21: 750), but where it has been rare in recent years.

*Caranx crysos*. Blue Runner. This species continues to be the most abundant Carangid in the Woods Hole area, having been noted from Sep-

tember 10 to October 20, 1955 in Benson's trap in Buzzards Bay, and in large schools in Woods Hole Harbor. Most of these were in the size range of 13-20 cm. fork length (about 6-8 inches) with a modal length of about 16 cm. This is somewhat larger than the modal length of the specimens reported by Mather (1954, *loc. cit.*) from offshore areas south of Martha's Vineyard on August 26 and September 10, 1953. There is thus some indication that many of the juveniles spawned offshore (Nichols, 1939, Bull. Bingham Ocean. Coll. 7: 1-19) or drifted northward in the Gulf Stream come inshore to the southern New England coast enroute to the southern habitat of the larger individuals.

*Caranx hippos*. Jack Crevalle. Although reported as common about Woods Hole, Mather (1954, *loc. cit.*) found it not so in 1953. In 1955, more than 100 were caught in Benson's trap in Buzzards Bay, September 9. Those were all about the same size; two measured were 27.5 cm. fork length. Later, from October 3-19, several specimens were taken in the same trap, but these ranged from about 13-20 cm., half the size of the September specimens. These latter are apparently rather large for northern specimens.

Three small specimens were taken by the ATLANTIS at a night light at 40°02'N, 70°42'W, July 7, 1954. They ranged from 2.4-3.1 cm. fork length.

*Rachycentron canadus*. Cobia. A specimen about 4 feet long was taken in Benson's Buzzard's Bay trap in early September 1951. There are only a few previous Woods Hole records for this stray, from July and September.

*Decapterus punctatus*. Round Robin. Eight small specimens, 2.7-4.9 cm. fork length, were taken at a night light from the ATLANTIS at 40°02'N, 70°42'W, on July 7, 1954.

*Selar crumenophthalmus*. Goggle-eye Scad. Twelve specimens from the Buzzard's Bay trap and from Woods Hole, on October 18 and 19, 1955 were 11-15 cm. fork length. These are all smaller than the series from Quisset, September 26-October 9, 1953 reported by Mather (1954, *loc. cit.*).

*Aleclis crinitus*. Threadfish. One specimen of this rare species (in northern waters) measuring 110 mm. fork length, was taken off the dock of the Woods Hole Oceanographic Institution, September 29, 1954.

*Lutjanus analis*. Muttonfish. Captain Charles A. Mayo, Jr., reported seeing a specimen about 30 inches long among the landings at Provincetown, Massachusetts on October 1, 1955. Captain Mayo, an experienced Florida fisherman, is well acquainted with the species. This specimen is the first Gulf of Maine record and probably the northernmost record.

*Mullus auratus*. Northern Goatfish. One specimen, 3.75 cm. fork length, was taken at a night

light from the ATLANTIS on July 7, 1954 at 40°02'N, 70°42'W.

*Otophidium welshi*. Welsh's Cusk Eel. A specimen, 161 mm. standard length, brought to us by Norman Benson, was taken in Tisbury Pond, Martha's Vineyard, October 1, 1954. It is now in the Museum of Comparative Zoology as number 39690. Previously this species had been reported only from the coast of the Gulf of Mexico (Allen, 1931, Copeia (1): 28; Woods, 1942, Copeia (3): 192), and from off New Jersey (Fowler, 1952, Proc. Acad. Nat. Sci. Phila. 104: 134).—FRANK J. MATHER III, AND ROBERT H. GIBBS, JR., Woods Hole Oceanographic Institution, Woods Hole, Massachusetts. Contribution No. 901.

**LABORATORY CARE AND FEEDING OF LARVAL LAMPREYS.**—During an investigation of the effects of various chemical compounds on larval sea lampreys, *Petromyzon marinus* Linnaeus, it was necessary to maintain numbers of ammocetes in the laboratory. Some method had to be worked out whereby lamprey larvae could be kept in good condition for an interval of at least six months. Reese (1900, Biol. Bull. Woods Hole, 1: 161-162), described how he kept fewer than 50 in aquaria for a short time. Other workers, (Gage, 1928, N. Y., Cons. Dept. Suppl. to 17th Ann. Rept.: 158-191; Leach, 1940, COPEIA (1): 21-34; and Applegate, 1950, U. S. Fish and Wildlife Ser., Spec. Sci. Rept. Fish, No. 55) have held ammocetes in the laboratory for varying lengths of time. These authors were not primarily concerned, however, with developing a technique whereby the larvae could be held over long periods. The procedure evolved to meet this problem is described in the following paragraphs.

Square, galvanized iron wash tubs of about 15-gallon capacity were painted inside with black asphaltum. They were then arranged on a sloping laboratory table in such a manner that a lip of each overlapped that of the next one down the slope. Filtered, dechlorinated tap water was run into the highest one of the series and spilled from it into the second and so on down through all of them. About four inches of washed, fairly coarse sand was placed in each tub. This proved to be a very satisfactory medium for the burrowing larvae.

The filter used to dechlorinate the water consisted of a stainless steel container seven inches square by thirty inches high. A graduated layer of sand and gravel was placed in this container. The coarse gravel, with stones about the size of golf balls, was at the bottom nearest the outlet. This base was built up with progressively smaller stones and terminated with a half-inch layer of coarse sand. The total depth of the stones and sand was approximately one foot. The sand was covered with a thin layer of cotton batting. On top of the cotton,

which served only as a separator, was a seven-inch layer of activated charcoal, topped with another layer of cotton about four inches thick. Tap water was directed in at the top in an amount that would yield one-half gallon of dechlorinated effluent per minute at gravity pressure. Under constant use this filter performed satisfactorily for as long as four months before reactivation of the charcoal was necessary.

The continued passage of this small flow of fresh water from one filter maintained satisfactory water quality for as many as 100 larval lampreys in each of four tubs at room temperature (70°-75°F.) for periods as long as six months. The water was aerated by ordinary aquarium air breakers.

On the basis of an early food study (Creaser and Hann, 1928, Pap. Mich. Acad. Sci., Arts and Letters, 10: 433-437) the lampreys were fed plankton from a series of five-gallon carboys of "green water" suspended over the tubs on a platform. Algal growths on the insides of the tubs were inhabited by many different species of protozoa. Presumably, the ammocetes utilized this source of food also. The bloom in the containers was held fairly steady by periodic fertilization with commercial inorganic fertilizer. A series of flood lights placed over the bottles provided sufficient light to maintain good plant growth. One gallon of this water was fed into each tub daily. If water was allowed to flow through the tubs all night, many ammocetes escaped over the edge of the tubs in the darkness. To avoid this, feeding was adapted to late afternoon. At this time, the inflowing water was shut off, and the water in each tub was drawn down about two inches from the edge just before addition of phytoplankton-containing water. The slow flow of dechlorinated water was started again each morning, and during the day flushed the holding tubs sufficiently. Alternate carboys were used each day. The volume of water taken from a food reservoir for a feeding was replaced at once with tap water. The small amount of chlorine introduced by the tap water did not seem to interfere with production of the plankton. Examination of the intestines dissected from several lampreys showed that they were actually ingesting this food. The fact that they maintained apparently excellent condition during several months indicated that they must also have been utilizing this food metabolically. None was measured to determine if growth occurred while in the tubs, however.—PHILIP J. SAWYER, Department of Zoology, University of New Hampshire, Durham, New Hampshire.

**OCCURRENCE OF THE BOAR FISH, PSEUDOPENTACEROS RICHARDSONI, AND THE ZEID, ALLOCYTUS VERRUCOSUS, IN THE NORTH PACIFIC.**—Four specimens, identi-

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fied as *Pseudopentaceros richardsoni* (Smith), family Histiopteridae, were taken in the North Pacific during the past summer by two United States Fish and Wildlife chartered vessels PARAGON and CELTIC. The locations of the specimens taken by the PARAGON were as follows:

Date	No. spec.	Location	Surface temperature
July 31, 1956	1	45°49'N by 160°03' W	12.2°C.
Sept. 15, 1956	2	49°00'N by 155°00' W	12.1°C.
Sept. 17, 1956	1	49°00'N by 150°00' W	13.2°C.

The location of the specimen taken by the CELTIC was at latitude 51°00'N and 150°00'W with a water surface temperature of 11.0° C. All specimens were taken near the surface in gill nets during a survey to determine the distribution and abundance of the Pacific salmon (*Oncorhynchus*).

*Pseudopentaceros richardsoni* was first found off the Cape of Good Hope and has occasionally been reported off New Zealand (Smith, 1951, Ann. Mag. Nat. Hist. Ser. 12, 4: 873). The finding of this species in the North Pacific extends the known range by about 5000 miles. Two of the four specimens were preserved; their counts and measurements are given below.

Counts are as follows: dorsal rays, XIV, 9; anal rays, IV, 7; ventral rays, I, 5; pectoral rays, ii, 14, i; caudal rays, i, 15, i; gill rakers 6 to 8 + 16 to 17; scale rows along lateral line 71 to 76; transverse series from front of first dorsal spine obliquely back to lateral line, about 11; thence to midline of belly, about 45; predorsal scales 14 to 16; 7 to 8 horizontal and 15 vertical series of scales on the cheek; vertebrae 12 + 12; and branchiostegals 7.

Measurements in mm. are: standard lengths, 240 and 254; depth, 104 and 107; head, 78 and 81; maxillary, 25 and 26; snout, 31 and 34; eye, 19 and 21; interorbital, 28 and 30; preorbital, 15 and 16; depth of caudal peduncle, 24 and 26; length of caudal peduncle, 31 and 33; snout to dorsal, 96 and 102; snout to anal, 190 and 200; snout to ventral, 119 and 124; snout to pectoral, 81 and 89; longest dorsal spine (3rd), 38 and 34; longest dorsal soft ray, 24 and 28; longest anal spine (2nd), 19 and 21; longest anal ray, 20 and 24; longest ventral ray, 48 and 50; longest pectoral ray, 68 and 72; longest caudal ray, 47 and 49; width at pelvic origin, 32 and 34; base of spinous dorsal, 108 and 112; and base of soft dorsal, 26 and 30.

All the larger spines of the fins are longitudinally striate, but other wise smooth. The dorsal is inserted over the hind margin of the opercle, none of the spines are abruptly constricted near the apex, and are heteracanth. Radiographs indicate that the third, fourth, fifth, and sixth dorsal spines each

have at the base an anterior lobate projection, the anterior of which is serriform, at least in spines IV, V, and VI. The anal fin is similar, with the second and third spines lobate anteriorly, the leading edge of the lobe of the third, and probably the second, with serrae. Attempts to lock the dorsal and anal spines manually were unsuccessful, but in other respects the mechanism appears similar to that described by Smith for *Quinquarius capensis*. Comparisons of radiographs also indicate many other skeletal similarities.

Similarities to *Quinquarius* also were noted in the presence of numerous large cephalic sensory pores roofed by membranes; the four large pores across the chin near the tip of the lower jaw; the pattern and sculpturing of the surface bones and scales on the head and body; the fine sharp conical teeth on the jaws and vomer; the strongly arched lateral line with simple, dorsally curved tubules; and many other characters.

We are in agreement with Dr. J. L. B. Smith that differences between the genera *Pseudopentaceros* and *Quinquarius* do not appear sufficient for distinguishing genera. Aside from slight differences in fin ray counts, gill raker counts, and vertebral counts, it might be mentioned that there is no nuchal scute showing externally in *Pseudopentaceros* although there is a hint of one in the radiograph; there are only four sensory pores across the chin instead of six; the scales are relatively small and more numerous in *Pseudopentaceros*; the space between and before the pelvis is slightly rounded, posteriorly forming a low ridge which continues to the anus; and the width at the pelvic origin is narrower than in *Quinquarius*.

In the light of these investigations, and the fact that *Pseudopentaceros richardsoni* has a similar "trigger" structure on the dorsal and anal fin to that found in *Quinquarius capensis*, it would appear that that latter genus is not firmly established and it is hereby suggested that the name *Quinquarius* be regarded as a synonym of *Pseudopentaceros*.

A rather extensive increase in the known range of *Allocyttus verrucosus* Gilchrist, family Zeidae, is indicated by the capture of a specimen, 105 mm. in standard length, in the North Pacific, about latitude 50° N and longitude 150° W (surface water temperature about 10.2° C). The fish was captured in a gill net fished by the United States Fish and Wildlife charter vessel CELTIC.

With but a few exceptions, the specimen agrees with the description given by McCulloch (1914, Comm. Australian Dept. Trades and Customs, 2 (2): 117).

Dorsal rays, VI, 34; anal rays, III, 32; pectoral rays, 20; ventral rays, I, 6; caudal rays, i, 11, i; branchiostegals, 7; gill rakers, 25; and lateral line scales, 88. There are four large, pointed scutes in a



line between the pectoral and anal fin insertions and 10 scutes in a line between the ventral fin and anal fin insertions. There are about 28 small scute-like scales on the two low ridges extending from each ventral fin to the isthmus and about 30 on the low median ridge of the abdomen.

Measurements in millimeters are as follows: standard length, 105; greatest depth (the belly was abnormally distended by the injection of preservative), 81; depth as measured between the first dorsal and anal spines, 69; head, 40; eye, 16; snout to dorsal, 59; snout to anal, 90; snout to pectoral, 45; snout to ventral fin, 63; maxillary, 14; snout, 11; interorbital, 12; longest dorsal spine, 12; longest dorsal soft ray, 15; longest anal spine, 8; longest anal soft ray, 16; longest pectoral ray, 19; longest ventral ray, 27; and longest caudal ray, 19.

The specimen differs from those described by McCulloch (*op. cit.*) in the number of large plates between the pectoral and anal fin and between the ventral and anal fin which number about eight in each row in McCulloch's specimens. However, Smith (1949, *The Sea Fishes of Southern Africa*, p. 146) in his figure, indicates about 7 or 8 scales in the former row and about 12 in the latter. The scales on the sides of the body of the North Pacific specimen do not appear to be imbricate, are without teeth, and are slightly elevated in the center. The specimen also differs from those previously described in having a smaller eye and somewhat greater number of soft rays in the dorsal, anal, and pectoral fins.—ARTHUR D. WELANDER, *School of Fisheries, University of Washington, Seattle 5*, RICHARD C. JOHNSON and RICHARD A. HAJNY, *U. S. Fish and Wildlife Service, Seattle 2, Washington*.

**NOTES ON WESTERN NORTH ATLANTIC SHARKS.**—Systematic records of shark captures have been kept by the Research Vessel ATLANTIS of the Woods Hole Oceanographic Institution for about the last three years. The data for *Prionace glauca*, *Eulamia falciiformis*, *Eulamia obscura*, and *Scoliodon tertiae-novae* in this paper come from that source and the author is indebted to the officers and crew of ATLANTIS, particularly Capt. W. Scott Bray. The writer is further indebted to Mr. George Berglund and Mr. Anthony E. Silva of Provincetown, Mass. and to Capt. Stanley E. Poole of Menemsha, Mass. for specimens of *Squatina dumeril*. Capt. Arthur C. Nelson of Woods Hole, Mass. collected the specimen of *Hexanchus griseus*. A/1c Gene A. McMahon of Lowell, Massachusetts captured the basking shark and Dr. Robert H. Gibbs, Jr. of WHOI provided the data from the white shark. The specimens of *Squatina* and *Hexanchus* have been deposited in the Museum of Comparative Zoology. This paper is Contribution No. 857 from the Woods Hole Oceanographic Institution.

*Hexanchus griseus* (Bonnaterre), the six-gilled shark. A female 236 cm. in total length and weighing 81 kg. was taken in an otter trawl near 41°55'N, 68°05'W on February 11, 1956. The depth was about 102 fathoms.

This species is common in the deep water north of Cuba but the only other western Atlantic records heretofore are one from near Currituck Lighthouse, North Carolina, and one from northern Argentina (Bigelow and Schroeder, 1948, *Fishes of the western North Atlantic*, 1: 84). The northernmost records in the eastern Atlantic are for Iceland (two, see Saemundsson, 1949, *The Zoology of Iceland*, 4 (72): 117), the population center being in the Mediterranean.

The stomach of the present specimen contained three cephalopod beaks; one pollock (*Pollachius virens*) about 60 cm. long; two skates, probably *Raja laevis*, both about 50 cm. long; and other fish remains including a flatfish.

The right ovary appeared to be the functional one and bore four or five prominent "scars", perhaps corpora lutea.

*Carcharodon carcharias* (Linnaeus), the white shark. A juvenile female of this uncommon shark 298 cm. in total length was taken in a fish trap in Cape Cod Bay two miles off the beach at Dennis, Mass., on August 16, 1956.

*Cetorhinus maximus* (Gunnerus), the basking shark. An immature female 396 cm. in total length was harpooned at the surface two miles off the beach at Sandwich, Mass. on October 18, 1956. This specimen had the produced, subcylindrical snout typical of juveniles. The gill rakers were lacking. Van Deinsse and Adriani (1953, *Zool. Mededel. Rijks. Natuur. Hist. Leiden*, 31 (27): 307-310) first pointed out that gill rakers are sometimes absent in this species. Recently Parker and Boeseman (1954, *Proc. Zool. Soc. Lond.*, 124: 185-194) have shown that in north European waters the gill rakers are shed about October and replaced by about February. Parker and Boeseman suggest that the fish "undergoes a resting, non-feeding, demersal stage" at this time. Van Deinsse and Adriani (*op. cit.*) report partly digested plankton in the stomach of a specimen without gill rakers and suggest that the rakers are thus not essential to feeding. Parker and Boeseman (*op. cit.*) also report such a specimen but argue that the stomach contents were in a somewhat advanced stage of digestion and may have been ingested before the rakers were lost. The stomach of the present specimen contained several gallons of a smooth, homogeneous, somewhat stiff, reddish-brown, greasy paste. This appears to be the normal contents of the pyloric limb of the stomach (Matthews and Parker, 1950, *Proc. Zool. Soc. Lond.*, 120: 548). In animals that have recently fed, the cardiac stomach contains

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material in which the whole or parts of individual plankters are discernible (Matthews and Parker, *op. cit.*). Thus while the stomach contents of our specimen perhaps supports the reasonable contention that individuals without gill rakers do not feed, the fact that the animal was actively swimming at the surface when captured (as it had been for two days previously) does not fit the notion of a demersal, inactive stage when gill rakers are absent.

*Prionace glauca* (Linnaeus), the great blue shark. The little that is known about development and reproduction in this presumably common and widespread animal comes mainly from Lo Bianco (1909, Mitt. Zool. Sta. Neapel, 19: 666). Data from four litters of pups taken from females caught at the surface by hook and line are summarized in Table I.

Our data together with those of Lo Bianco (1909, *op. cit.*) suggest that the seasons of mating and pupping are not restricted as they seem to be in the white-tip (*Pterolamiops longimanus*), another common high-seas shark (Backus, Springer, and Arnold, 1956, Deep-Sea Res., 3: 185-186). Lo Bianco reports embryos from 16 cm. in length to those "apparently completely developed" (this would be about 50 cm.) taken in the Mediterranean during May and June.

*Scoliodon tetrarhynchos* (Richardson). A male about 75 cm. in total length was taken at the surface on July 13, 1956 in 18°49'N, 61°57'W (about 65 miles N of Barbuda) where the water depth is about 3300 fathoms. The specimen is of interest because Bigelow and Schroeder (1948 Fishes of the western North Atlantic, 1: 300) say "so far as we are aware it has never been reported more than a mile or two out from the land or from water more than a few fathoms deep." Springer (1950, Amer. Mus. Novit., 1451: 7) reports specimens from the surface over more than 200 fathoms at Bimini but only several miles off the shelf.

TABLE I

DATA ON EMBRYOS, BLUE SHARK (*Prionace glauca*)

Position	Date	Length of mother	No. of embryos			Total length of embryos
			Male	Female	Total	
37°06'N 65°00'W	23 Sept. 1954	277 cm.	17	17	34	294-335 mm.
35°00'N 65°00'W	25 Sept. 1954	302 cm.	26	37	63	90-118 mm.
32°00'N 59°25'W	13 Nov. 1954	256 cm.	—	—	14	—
33°00'N 64°00'W	10 Oct. 1955	251 cm.	18	17	35	130-153 mm.*

\* One embryo, about 100 mm. in length, was dead in the mother.

TABLE II  
RECORDS OF *Eulamia falciformis*

Position	Date	Sex	Total length
19°33'N, 75°09'W	20 March 1953	M	c. 90 cm.
19°15'N, 75°10'W	21 March 1953	F	103 cm.
19°05'N, 75°05'W	22 March 1953	F	110 cm.
19°05'N, 75°06'W	29 March 1953	F	97 cm.
38°00'N, 68°00'W	19 October 1954	F	c. 115 cm.
37°44'N, 68°14'W	20 October 1954	F	152 cm.
11°30'N, 60°45'W	27 February 1955	F(2)	61, 201 cm.
11°30'N, 60°45'W	27 February 1955	M(5)	122, 145, 149, 150, 173 cm.

For the time being I follow Springer (*op. cit.*) in regarding the sharpnouted *S. lalandi* (Müller and Henle) as a distinct species. The present specimen has a short, broad snout and the critical head measurements fall within the limits given by Bigelow and Schroeder (*op. cit.*) for *S. tetrarhynchos* (*s. strict.*). I can add little about the presence or absence of a mid-dorsal ridge in this species, not having seen the present specimen in a fresh condition. Springer (*op. cit.*) has observed the ridge in *S. lalandi* but did not find it in fresh Mississippi specimens of *S. tetrarhynchos*. The present specimen has a faint suggestion of this structure (which often disappears after preservation). However, if it were no more evident in a fresh specimen it would probably be regarded as absent.

*Eulamia falciformis* (Müller and Henle), the scythe-fin shark. Our records (Table II) are from hook and line captures at the surface and add little to the concept of the geographical distribution of this little-known shark as delineated by Bigelow and Schroeder (1948, Fishes of the western North Atlantic, 1: 332-333). All are from tropical waters save two near latitude 38°N taken in October when the water there is at about its maximum temperature. The depth of water where our captures were made varies from about 250 fathoms to 3000 fathoms and the distance offshore from about 12 to 240 miles.

In deep water in the eastern Cayman Sea between March 18, 1953 and April 2, 1953 four specimens of this species and 15 specimens of the white-tip shark (*Pterolamiops longimanus*) were taken, these being the only sharks observed there. In 11°30'N, 60°45'W (north of Tobago I., about 12 miles offshore in a water depth of 250 to 300 fm.) seven specimens were taken within a half-hour and many more were seen about the vessel.

The color of *E. falciformis* has been described as "dark gray above, grayish white below" or "after preservation . . . mouse gray above and a paler shade of the same tint below" (Bigelow and Schroeder, 1948, Fishes of the western North Atlantic, 1: 332). Fresh-caught specimens are a grayish-brown

above with a peculiar brassy overtone. The under-sides are of the purest, most gleaming white. As soon as the shark is handled on deck a bit, it becomes a uniform gray beneath because of its placoid scales which cause a very even soiling. The upper parts become grayer and darker as soon as the shark dies. When the shark is viewed at large, swimming in clear water a few feet beneath the surface, the upper parts appear a handsome golden-brown.

We have examined seven stomachs of which two were empty. In the remaining, cephalopods occurred in four (one cephalopod had many photophores); fish in three; garbage in one; and one had some red roe probably from a fish.

All of our captures have been of juveniles or perhaps, in one or two cases, young adults. *E. falciformis* is active by both day and night.

*Eulamia obscura* (Lesueur), the dusky shark. This species is known from Cape Cod to Brazil in the western North Atlantic. However, "information in its occurrence south of Florida is scanty", (Bigelow and Schroeder, 1948, Fishes of the western North Atlantic, 1: 388) so we report the following specimen: a male, 271 cm. in total length taken in the night at 18°40'N, 65°45'W (about 15 miles offshore north of San Juan, P. R.) on March 8, 1954 by hook and line at the surface in about 800 fathoms of water.

*Squatina dumerili* (Lesueur), the angel shark. A female 117 cm. in total length was found dead in the intertidal zone of Nashaquitsa Pond (41°19'.8N, 70°49'.7W), at Menemsha, Martha's Vineyard, about December 6, 1955. This specimen weighed 15.4 kg. Fish remains, including a portion of vertebral column about 18 cm. long, were found in the stomach. Ten eggs, 35 to 50 mm. in diameter, were found in the left ovary. This specimen bore no indication as to why it died. Surface water temperature at Woods Hole at the time that this specimen was found was between 41° and 42°F.

On December 4, 1956 a male 107 cm. in total length was taken in an otter trawl in Provincetown Harbor where the water depth was 15 fathoms. This specimen weighed 10.7 kg. The stomach was empty.

This species has been reported from Martha's Vineyard, Mass., south to Jamaica (Bigelow and Schroeder, 1948, Fishes of the western North Atlantic, 1: 542). It is most common off the Central Atlantic States. The two previous Massachusetts records come from Menemsha, the northeasternmost locality from which the species had been reported. In addition to the present Menemsha specimen, one was taken in a fish trap there on September 1, 1873 (Baird, 1873, Rept. Comm. Fish and Fisheries, 1871-1872: 827; Smith, 1898, Bull.

U. S. Fish. Comm., 1897: 89) and another on September 23, 1921 (Smith, 1922, Copeia, 106: 33). All Massachusetts specimens have been between 90 and 120 cm. long. The nearest localities from which other records come are Newport and West Passage, Rhode Island.—RICHARD H. BACKUS, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts.

**RANGE EXTENSION FOR THE WESTERN MUDMINNOW, *NOVUMBRA HUBBSI* SCHULTZ**—In the course of assessing the juvenile chinook salmon migration out of the Deschutes River at Olympia, Washington, two specimens of the mudminnow, *Novumbra hubbsi* Schultz, were found. This is the first record of this species in the Deschutes. As far as is known this is the second watershed in which *Novumbra* has been found. Heretofore the species has been obtained only from the Chehalis River watershed, specifically from the Satsop River and from the Humptulips River.

On the 10th of March 1956, in the course of fishing an inclined plane salmon trap near the Deschutes River mouth, the first mud minnow was discovered. On the 18th of March another was caught. The trap was fished continuously for the rest of the summer until it was shut down on the 10th of October, but it caught no additional mudminnows.

The first specimen weighed 2.1 gms. and was 56 mm. long. The second was 1.9 gms. and 57 mm. long. Both mud minnows were observed for several months in an aquarium and are now in the fish collection at the University of Washington School of Fisheries.

A possible means of entry into the Deschutes may have been Johnson Creek, tributary to the Chehalis River system, which originates in a swamp that drains two ways—to the Deschutes and to the Chehalis. It is likely that periods of heavy precipitation make this swamp into a shallow lake.—J. W. FITZGERALD, Washington Department of Fisheries, Olympia, Washington.

**THE BONEFISH, *ALBULA VULPES*, IN TEXAS.**—A specimen of the bonefish, *Albula vulpes* Linnaeus, was taken in a trawl on the brown shrimping grounds at 21 fathoms, ESE of Port Aransas, Texas. This fish, believed to be the third Texas specimen, is 258 mm in standard length, and was captured on the night of December 15, 1956. It is in the museum of the Marine Laboratory in Rockport, Texas.

The earlier records of a bonefish in Texas by Gunter (1941, Amer. Midland Nat., 26: 197) and Baughman (1950, Texas Jour. Sci., 2 (1): 125)

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refer to the same specimen and are apparently based on the remarks of sports fishermen, for neither of the authors had the specimen.

The second Texas specimen, 428 mm standard length, is apparently unreported. It was taken by trawl on October 22, 1951, at 19 fathoms 45 miles south of Port Aransas. The mounted fish is on display at the Rockport Marine Laboratory, Texas.—TERRANCE R. LEARY, *Texas Game and Fish Commission, Rockport, Texas.*

**TWO RAPID FATALITIES FROM STONE-FISH STABS.**—The stonefish (*Synanceja verrucosa* Bloch) occurs in most intertidal areas, and to at least ten fathoms below, over a vast area of the tropical Indo-Pacific. This creature is everywhere rightly dreaded for the potency of its pain-producing venom, a powerful neurotoxin, whose injection not infrequently kills. An account of my own experience from a stab in the hand, while working in the Pinda area of Northern Mozambique (14°10'S x 40°40'E) appeared in Copeia (1951, 3: 207-210).

During the past ten years we have carried out a series of expeditions covering most of the Western Indian Ocean, and continually encountered or heard of those who had been stabbed by this dreaded fish. The circumstances of two rapidly fatal cases are outlined below.

A favourite bathing spot at Mahé, Seychelles is Pont Larue, where the bottom is mainly sand and the water relatively shallow. Some distance from the shore there is a group of rocks whose tops remain above the water. In March, 1956 an Indian youth of 15, well-built and athletic, was swimming there and came towards the rocks. As he trod he felt a stab in the sole of his foot. He pulled himself up, sat on the rock and then saw three punctures. By this time intense pain had developed at the site of the punctures, which spread rapidly up the leg to the body. In a short time he was in agony and showing signs of collapse. Alarmed by his appearance the others managed to find a pirogue in which he was taken to shore. By this time he had turned blue and was frothing at the mouth. He was at once put in a car that set out for the hospital, but he died on the way there.

According to the medical officer who examined the body, this was greatly cyanosed, and the apparent cause of death was a cardiac or respiratory poison that had been injected. His medical attendant reported that he had not suffered from heart trouble.

At Pinda, Mozambique, on the 23rd September, 1956, two men went out in a canoe to the margin of the reef, close on 5 miles from land, and near low tide went wading, hunting for fishes with spears. The elder soon noted that the other had col-

lapsed in the water. Hastening over, he found his companion almost delirious, but able to say that he had been stabbed in the foot by a "sherowa" (*Synanceja*). Others came to help; the wounded man, now unconscious, was carried to the nearest canoe, and the stonefish was found and killed, cut open and the gall-bladder extracted, for the natives believe this, swallowed, to be an antidote to the poison. The victim was by then unconscious and well within an hour was dead.

I examined the corpse later. There was only one stab in the front of the second toe of the right foot. It was close on  $\frac{3}{4}$ " deep and went along the bone. The man must have kicked against the stonefish from behind. There was neither discoloration nor swelling in the toe or foot and from the rapidity with which he succumbed the toxin may well have been injected directly into a bloodvessel. The victim was between 30 and 40 years of age and apparently, as well as from enquiry, strong and in good health.

It is of interest to note that although the home of this man was some way inland, with a burial site adjacent, as he had died out at sea, it was custom that he should be buried at the sea. The corpse was washed in seawater, wrapped in his blanket and placed on the right side, facing the sea, in a grave  $4\frac{1}{2}$  ft. deep dug on the very edge of the beach above high water mark. The body was held in place by a palisade of adjacent 3 ft. stakes forced in obliquely, all this first covered with grass well trampled in, then with sand. During the excavation of the grave most of the skeleton of a human male was found—unknown to the "mourners", but according to them, also a man who must have died at sea, possibly a "sherowa" victim of the past times. Women are not permitted to attend funerals, not even of a woman.

In response to our queries we were told that "four or five" people had died from stonefish stabs in recent times, none so quickly as this last victim. One had died some days after, another some weeks, one after more than a year. All those who died had suffered continual pain and ill health, in one case a leg had rotted off. All who were stabbed suffered for long periods. One victim of four months before showed me his foot—there were two stabs—both healed, but the foot was scarred and deformed. For almost three months he had been unable to walk and was still not fully recovered.

It is likely that those who survive the first terrible effects of the toxin die from secondary infections, easily acquired in tropical areas with wounds such as these, that, initially at least, are in degree gangrenous and remain open for considerable periods.—J. L. B. SMITH, *Rhodes University, Grahamstown, South Africa.*

THE PROLONGED SPAWNING OF THE ROSYFACE SHINER, *NOTROPIS RUBELLUS* (AGASSIZ), IN NORTHWESTERN PENNSYLVANIA.—The spawning behavior of this common cyprinid was reported by Pfeiffer (1955, Copeia, (2): 95–104). His observations were made on Five Mile Creek, a small tributary of the Allegheny River, New York. In French Creek and Slippery Rock Creek, northwestern Pennsylvania, judging from my own investigations of 1954, 1955, and 1956, the same species selects a different spawning site and has a relatively prolonged period of reproductive activity.

Observations for 1954 are typical. On May 26, 1954 *Notropis rubellus* males and females in striking breeding colors were observed massed over the gravel nests of the river chub, *Hybopsis micropogon* (Cope), and the hornyhead chub, *Hybopsis biguttatus* (Kirtland). During and after the chubs spawn, their nests are used by other fishes as spawning sites. The nest associates and interrelationships of the chubs are discussed and summarized by Lachner (1952, Amer. Midl. Nat. 48 (2): 435–436). The reproductive behavior of the rosyface observed in Slippery Rock Creek and French Creek on May 26 was basically the same as described by Pfeiffer. Although brightly colored *N. rubellus* began massing over the chub nests ten days prior to this date, no spawning activity was observed. Sixty-eight nests were found in 1954 with *rubellus* spawning over them. Spawning ceased over the nests after six days. French Creek was rechecked early in June to collect the newly hatched larvae, and *rubellus* were found spawning in the smaller riffles which had only a few inches of water flowing over them. Spawning activities in these areas were recorded on June 10, 18 and 25 in French Creek and Slippery Rock Creek. The rosyface, after the initial six day spawning over the chub nests, never return to these sites. This was also true in 1955 and 1956. One marked difference in the late spawning activity was the decrease in the number of participating individuals. In the earlier period, 45 to 60 *rubellus* were seen spawning over the chub nests with an approximate 1:1 sex ratio. The late spawners numbered from 15 to 25 individuals. A predominance of males were noted at this time. In 1954 the final spawning occurred on June 25th. The observations made in 1955 corresponded to those of 1954. In 1956 the extremely cool spring apparently caused a delay in spawning of *rubellus* until June 1 and the season finished later, July 3rd. The rosyface shiner thus has a five week spawning period in northwestern Pennsylvania. This approximates the time period reported by Adams and Hankinson (1928, Bull. New York State Coll. Forestry, Syracuse Univ., 1 (4a): 235–548) for 1916. The

water temperature on the first day of spawning ranged from 68°F. to 72°F. for the three years.

Two experiments were designed to gain a better understanding of the relationship between *rubellus* and the *Hybopsis* spawning site. A piece of white gauze was placed over the center of a nest on which individuals of *N. rubellus* were spawning. The rosyface scattered but soon returned to the nest. They would not spawn but quickly swam back and forth over the nest and gauze. The cloth was then placed to one side of the nest. Spawning occurred over that portion of the nest without the cloth. At no time did the members of this breeding group desert the disturbed nest and spawn on the adjacent nests less than six feet away. There is thus an apparent relationship between a spawning school and a particular nest during the early stages of the breeding season. This is further substantiated by the second experiment. Five *Hybopsis* nests were flattened out in order to see if the breeding schools would return to their sites. In all five cases they did return and continued to spawn. Since the *Hybopsis* nests are made of small stones which are often deposited with the dark, bottom side up, there may be some visual stimulation affecting the rosyface's choice of spawning site.

The distance and number of eggs carried by the current were investigated. A plankton net was placed behind a nest where *rubellus* were spawning and a sample of eggs was taken five times. The eggs drifted at least twenty inches to the net. The mean number of eggs recovered in this manner was twelve.

Three species were seen on many occasions feeding on the eggs being deposited on the nest: the rainbow darter, *Eltheostoma c. caeruleus* (Storer), the hognose sucker, *Hypentelium nigricans* (LeSueur) and the stoneroller minnow, *Campestris anomalum* Agassiz. Stomach analysis of these species showed numerous eggs present.—ROGER J. REED, Pennsylvania Fish Commission, Conneautville, Pennsylvania.

OCCURRENCES OF THE OCEAN SUNFISH, *MOLA MOLA* (LINNAEUS), IN TEXAS.—In the summer of 1949, J. P. Breuer, marine biologist for the Texas Game and Fish Commission, sighted *Mola mola* on two occasions in the Gulf of Mexico off Sabine Pass. He was unsuccessful in attempts to capture one of the specimens.

Baughman's "Random Notes on Texas Fishes" (1950, Texas Jour. Sci., 2: 257) reports a Rockport, Texas fisherman having seen a strange fish which may have been *Mola mola* in the Gulf at Cedar Bayou on February 4, 1950.

In the summer of 1952, George Roberts harpooned a *Mola mola* off Port Isabel, Texas. An

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excellent photograph authenticates this record. The specimen was approximately four feet total length.

On February 9, 1957, an ocean sunfish was found washed up on North Beach in the city of Corpus Christi. This locality, in Corpus Christi Bay, is approximately 20 miles from the Gulf, an unusual occurrence for an oceanic fish. When observed by the author on that same day, most of the fins were gone and the odor of decomposition was very strong. No measurements were taken, but the fish was approximately four and one-half feet long and weighed an estimated 200 pounds.—ROBERT J. KEMP, JR., *Texas Game and Fish Commission, Rockport, Texas.*

**AVOIDANCE OF POISONOUS EGGS OF THE MARINE FISH *SCORPAENICHTHYS MARMORATUS* BY PREDATORS.**—It has been reported by workers in California (Hubbs, C. L., and A. N. Wick, 1951, *Calif. Fish and Game*, 37 (2): 195-196) that the eggs of the cottid *Scorpaenichthys marmoratus* Girard are poisonous to rats, guinea pigs and man. There is, it appears, no record of these eggs being poisonous to birds, nor to other than the experimental mammals (man was the inadvertent first experimental species). At the suggestion of Dr. Hubbs the present writer here sets out his observations concerning these eggs and certain birds and predatory mammals.

The species is known to workers in British Columbia as the "Giant Marbled Sculpin" and is so called herein. In California it is known as the "Cabezon," a name applied to quite a different species in B. C.

*Scorpaenichthys marmoratus* deposits its eggs in masses up to half a meter across by four centimeters thick, from January to May, on rocks in the subtidal fringe in the southern Strait of Georgia. Here they are conspicuous objects, bright maroon to crimson in color, never yellowish green as reported by some observers.

Egg masses of this species were seen in the years 1953, 1954, 1955 and 1956, on the southwest side of Saturna Island which is on the Canadian side of Boundary Pass, north of the San Juan Islands. Particular masses were kept under continual observation until early August. Hatching has repeatedly been seen taking place about the end of the first week of August.

In 1953 one particular egg mass was seen on a reef running out from Payne Point, the southwestern corner of Saturna Island. It was about 3½ meter above zero tide level, and from May 12 to August was exposed on three days or more every two weeks, when tides were extremely low. (It should be explained for non-Canadians that "zero"

tide level here means the level of lowest normal tides, not the same as the zero of U. S. tide tables. In British Columbia, zero or near-zero tides occur every two weeks from mid-April to early August, though 1956 was an exceptional year, with the interval being one month.) At the same period the reef was a roosting place and feeding area for several glaucous-winged gulls, northwest crows and Baird's cormorants. There was an occasional raven. In addition, the reef is a hunting ground for mink and one or two raccoons, both seen here repeatedly by the writer.

During all this time, mid-May to August, the egg mass remained untouched so far as could be seen. It was not hidden nor inconspicuous. In fact, like all others, it was first seen from a passing boat 100 feet distant. Also, it was on a sloping rock surface and easily accessible to all the named animals.

The same year, 1953, two other egg masses were seen along the cliffs a few hundred meters east of the reef, and at the same tide level. In subsequent years up to and including 1956 other egg masses have been seen in much the same localities, though not on the Payne Point reef.

In view of the facts given above it appears that egg masses of the giant marbled sculpin are not used as food by fish-eating or scavenging birds, nor are they eaten by predatory and scavenging mammals such as mink and raccoon.

The gulls seen nest in a colony about 4 miles (7 km.) east. The crows are very common, forming a flock of about 40 to 60 birds that scours the island. The cormorants roost on the cliffs nearby at night to about 20 in number, and daytimes they roost on the reef and rocks at the foot of the cliffs, fishing alongshore. Mink and raccoons are of course chronic shore-scurers, taking mussels, crabs, gastropods and anything else that looks edible. They have often been watched from a distance of a few meters by the writer. Yet there has not at any time in four seasons been any indication of interference with these eggs by any agency up to the time of hatching. Observation was partly a matter of collateral study on the intertidal communities, and partly due to encouragement by a daughter who always wants the hatching eggs for her camp aquarium.

It seems probable that these eggs are recognized by predators, including birds, as not being food. Recognition may be by light value, as the eggs are at least as bright and of the same color range as the red urchins (*Strongylocentrotus franciscanus*) which occur in the same place, and up to 2 meters above zero level. Both these and the green urchins (*S. drobachiensis*) which also live here are eaten regularly by the gulls and crows. Another possibility is that the masses are too tough for the animals



to use, as they are quite rubbery, the eggs being cemented together. But this seems quite unlikely, in view of other tough foods.

It would appear at present that any avoidance is due to experience, the eggs being unpalatable, or else repellent to smell although there is no odor perceptible to the human senses. Whether or not this a true avoidance and if so, how it is developed, can apparently best be studied by experiment with captive birds and other scavenging animals.—R. W. PILLSBURY, *University of British Columbia, Vancouver, Canada.*

**NUPTIAL OR PRE-NUPTIAL BEHAVIOUR OF THE SHAD, *ALOSA SAPIDISSIMA* (WILSON).**—Mr. H. C. White (recently retired from the Fishery Research Board staff) and the author observed a peculiar behaviour of shad from the bridge across the Southwest Margaree River, Nova Scotia, at Scotsville (N. Lat. 46°, 12'; E. Long. 61°, 9') about three o'clock in the afternoon on June 20, 1935. This was described in some detail in an unpublished Biological Stations report (No. 117) filed shortly afterwards by the author. To the best of the writer's knowledge nothing similar has been recorded by students of this species.

The Scotsville bridge is about 1 mile below the point where Lake Ainslie, a clear, shallow lake 10 miles long and 5 miles wide, suddenly narrows and becomes the river. At that time the water surface was approximately 8 feet below the bridge, the depth 7 feet at mid-stream, the flow about 40 feet a minute, the temperature 18°C and the visibility through the clear, colourless water excellent because it was a bright, calm day. The school of shad (25 fish counted) studied was first noticed when it was about 30 feet below the bridge. It was composed entirely of adult shad of an almost uniform size 20 to 30 inches long swimming 3 to 4 feet below the surface. There was no doubt about their specific identity because in the next few minutes we were able to view them constantly and observe their general colouration, large scales and the series of dusky spots along the sides.

When first sighted the fish were swimming rapidly up-stream in single file behind a leader which, so far as we could determine, maintained the leadership throughout the period of our observations. When they arrived close to the bridge the line slackened its speed and began a counter-clockwise circling (6 to 8 feet diameter). This continued for roughly 1½ minutes but as it proceeded the speed increased gradually and the diameter of the circle decreased until the arched bodies of the fish were whirling at a startling rate in a path no more than 2½ feet in diameter. The crowding was such that each fish was frequently bumping its nose into the

one immediately in front. This, apparently, sometimes displaced, but did not dislodge, scales which remained as shining silver spots on the sides of the fish.

When the speed of whirling at the center reached what seemed an incredible speed, the seemingly tireless leader flashed off to the right then headed straight up-river for about 50 feet and again began circling slowly in mid-stream. The others followed, trailing off in single file, and the whole process just described was re-enacted. As it went on the current carried the school back downstream to the bridge almost but not quite to the place where the previous gyration had ended. In the 10 minutes we were able to view them the fish staged this peculiar performance 6 times without any observable difference in pattern of behaviour. It was apparently continued further up-stream but surface reflections made it impossible for us to observe it.

Hoping to get a specimen for positive identification Mr. White borrowed a fishing rod from a lad who was on the bridge and tried to entice the fish with a hook baited with angle worms. They displayed not the slightest interest. Mr. White was equally unsuccessful in trying to "jig" them with a bare hook. The fish were not frightened by this at all nor by beating the surface of the water with the rod itself. Later, the writer identified a typical specimen taken July 9, 1935, in an alewife brush weir set just below Scotsville.

Weirmen also recognized the fish as shad and stated that the 1935 run was the largest for many years. Villagers did not know the species. Several of them had previously reported seeing 30 "salmon" below the bridge on the afternoon of June 13, 1935, which would not strike fly or worm and circled in a peculiar way for half an hour. Undoubtedly the "salmon" were shad and their behaviour the same as has just been described.

Despite the turmoil, there was no suggestion of cloudiness of the water about the fish which might possibly have been expected if these fish had been spawning. Besides this, shad spawning ordinarily takes place at night (Leim, 1924, *Contrib. Canadian Biol.*, 2 (11): 163-284). Furthermore the whirling was quite different from "washing", the shad's frequently-described accessory behaviour at spawning (Mansueti and Kolb, 1953, *Maryland Dept Res. Educ.*, 97: 1-293); washing takes place close to the surface and seems to involve single fish only. For these reasons it might be concluded that the Margaree shad were not spawning, but this is not certain. We were of the opinion, however, by the religiousness of this group performance that it is a regular behaviour pattern of shad and not a series of chance incidents.

In seeking an explanation for what we witnessed



Mr. White suggests that it may have been a device for natural selection of vigorous parent stock; that the leader may have been a ripe female, her followers males competing for her much as drones compete for the queen bee during her mating flight and that mating may occur between the leader and the most vigorous male, either during the circling

process or later and more leisurely when other males have wearied of the mad chase the female has led them.

The author acknowledges assistance in preparing this account from Mr. H. C. White and Dr. A. H. Leim.—J. C. MEDCOF, *Fisheries Research Board of Canada, St. Andrews, New Brunswick.*

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